

The scientific studies and expert judgment have sought to answer two questions about the health risks of OII: Are there any known hazardous chemicals emanating from the site that can be detected in the surrounding neighborhoods? Are there any demonstrable ways in which the health of current residents differs from the health of people living in nearby control communities? We consider each question in turn.

The Regional Water Quality Control board has monitored the ground water supply continually since 1976 and has found no evidence of contamination. In April, 1983 the off-site level of vinyl chloride, a carcinogen, was measured at 19 ppb, which exceeds the California regulatory level of 10 ppb. However, workers experiencing exposures 170 to 500 times these levels have not experienced health problems and more recent random samples of air within homes showed no detectable levels of vinyl chloride gas (above 2 ppb). No other hazardous chemicals have been detected in appreciable quantities in off-site air monitoring. Thus, Satin, Huie, and Croen (1986) in a study conducted by the California Department of Health concluded that "the recent environmental monitoring of the area indicates that with the levels of chemicals found, long-term (health) problems would not be expected to occur."

The one potentially serious carcinogen detected off-site is vinyl chloride. Calculations of the cancer risk from exposure to vinyl chloride in the highest amounts detected therefore provide an upper bound to the risk. The USEPA (1985) Carcinogen Assessment Group estimated that the unit risk for exposure to vinyl chloride over a 70-year lifetime at a concentration of  $1 \text{ mg/m}^3$  is  $2.6 \times 10^{-6}$ . The concentration of  $1 \text{ mg/m}^3$  corresponds approximately to a concentration of .38 ppb, which, if adjusted

linearly from a 70-year exposure to a one-year exposure, is equivalent to 26.9 ppb, 140 percent of the highest monitored level of OII. Dividing the EPA unit risk for exposure by 1.4 gives an estimated annual risk of  $1.86 \times 10^{-6}$  for residents exposed at 19 ppb for one year. However, residents nearest OII have lived there as long as nine years (since 1977). The maximum cumulative risk might then be as much as nine times higher or  $1.67 \times 10^{-5}$ . It should be noted that these risk calculations are likely to be serious overestimates because the 19 ppb level represents the highest 24-hour average value ever obtained near the site and because vinyl chloride concentrations have been below detection since then. Thus, our assumed exposure of 19 ppb cannot be characterized as typical for any individual living near the site but rather represents an extreme upper bound for possible exposure.

A second approach to assess the health risk has been to compare health status of residents living near OII to others living in the Los Angeles metropolitan area. A study conducted by the Los Angeles County Department of Health Services in 1983 concluded that no consistent pattern of absences from school had occurred around the landfill. Nearby residents had not suffered excess mortality, nor had they experienced more adverse outcomes of conception than had residents in other parts of Los Angeles County. Of course, current epidemiological studies may not indicate serious health effects that may arise in the future because of, for example, the long latency periods for many types of cancer.

The California Department of Health has conducted a survey of residents living near the OII Landfill and residents of comparable control communities approximately ten miles away. There were no statistically

significant differences between the OII area and the control communities in terms of mortality or increased incidence of adverse pregnancy outcomes, cancer, and liver disease. There was a statistically significant difference in self-reports of headache, sore throats, sleeping problems, eye and skin irritation, and feeling tired (see California Department of Health Services, 1986). These reported health problems were greater in those neighborhoods near OII where odor was more frequently a problem. However, toothaches were also more frequently reported in neighborhoods located near OII. Because there is no known biological mechanism for toothache involving any of the possible toxic chemicals at the landfill site, this finding suggests that residents may have simply monitored their health more carefully or just remembered these minor health problems better because they were aware of the possible association with OII.

In summary, although the OII Landfill is not a pleasant place, there is no indication that it has caused serious health problems, nor is there reason to believe, based on water and air monitoring, that there are likely to be major health problems in the future. The possibility does remain that there is some as yet undetected toxic chemical associated with one odor from the landfill.

#### 4.4 Residents' Judgments of the Health Risk.

In the fall of 1985, we conducted a mail survey to gather judgments of health risk from people living near the OII site. From maps, reverse telephone books provided by Pacific Bell, and records of real estate transactions, an address list of 1912 residences near OII was constructed. Surveys were mailed to all 1912 known addresses. Using standard follow-up reminders (Dillman, 1978), we obtained responses from 768 residents, which

after adjustment for bad addresses represent 45 percent of the original sample.

The survey questionnaire assessed residents' beliefs about health and safety risks, odor problems, sources of information about the site, and attitudes towards local, state and federal officials, the news media and landfill operators. The questionnaire also included standard sociodemographic questions.

On a "risk ladder" (see Figure 4.2) respondents matched their belief about the risks they faced from the OII Landfill to specific levels of risk defined in terms of the probability of death. Respondents reported retrospectively their belief about risk before site closure as well as their current belief about risk after site closure.

Figure 4.3 shows on log scales the frequency distributions of subjective health risk both before and after closure of the OII Landfill. There are two striking features of the frequency distribution of subjective health risk before closure of the site. First, there is a wide diversity of opinion; every category on the risk ladder received responses. Second, the distribution is bimodal with a sizable proportion of the respondents estimating the risk around  $10^{-3}$  and  $10^{-2}$ , approximately the risk of smoking at least one pack of cigarettes per day and another segment of the sample clustering around estimates of the risk between  $10^{-5}$  and  $10^{-6}$ , approximately the risk from the average consumption of saccharin. In other words, some residents believed the risk to be very large whereas others judged the risk to be very small.

In Chapter 3 we obtained a similar bimodal distribution of responses in a laboratory study of risk decision making with low probability risks. The distribution from the laboratory experiment was very similar to the

FIGURE 4.2

**RISK LADDER**  
(numbers on steps are deaths per million people per year)

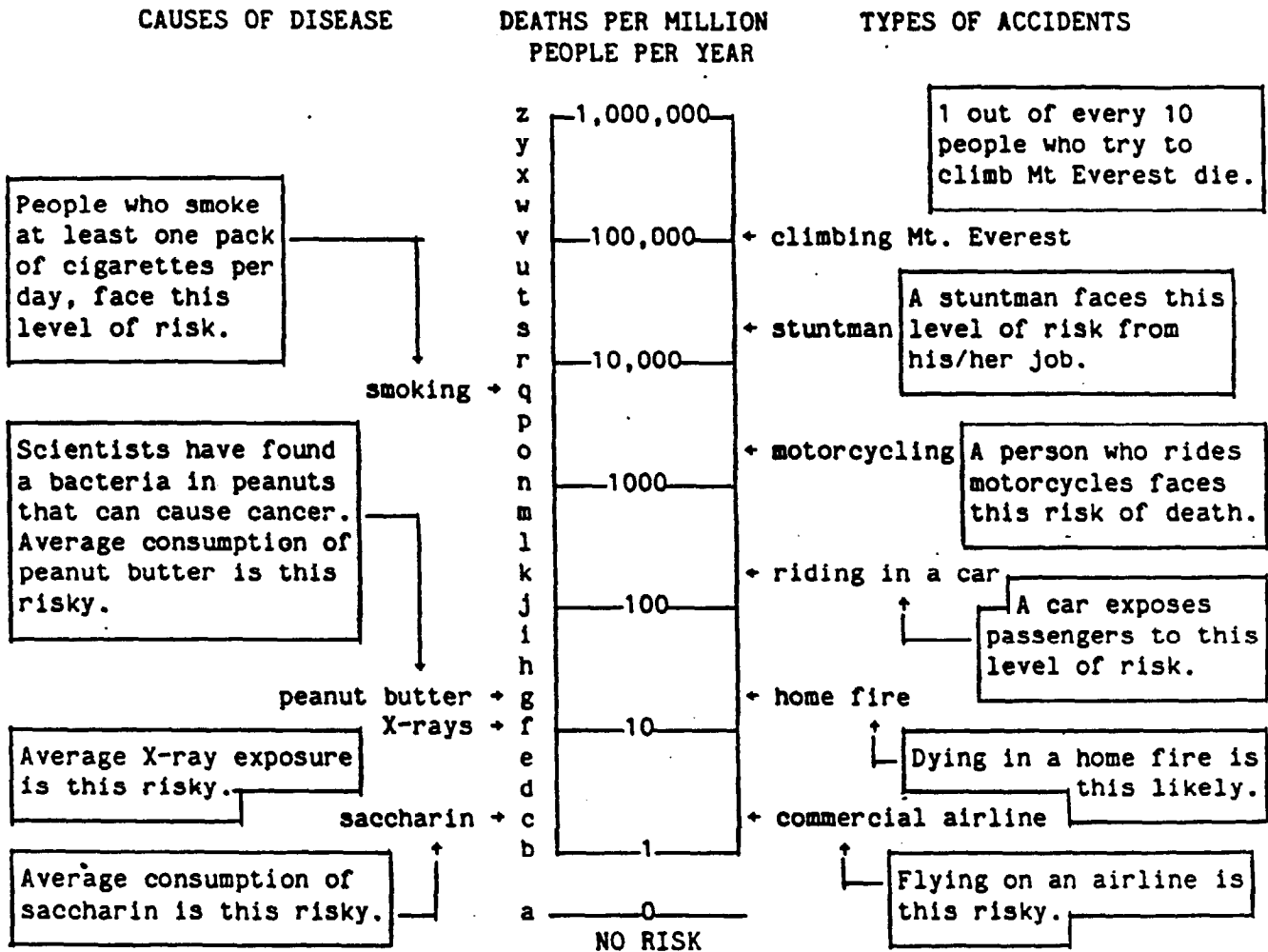
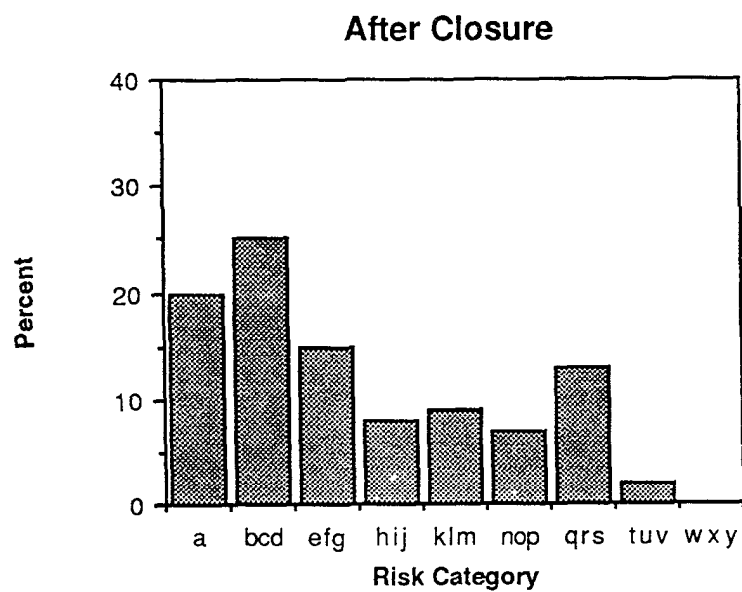
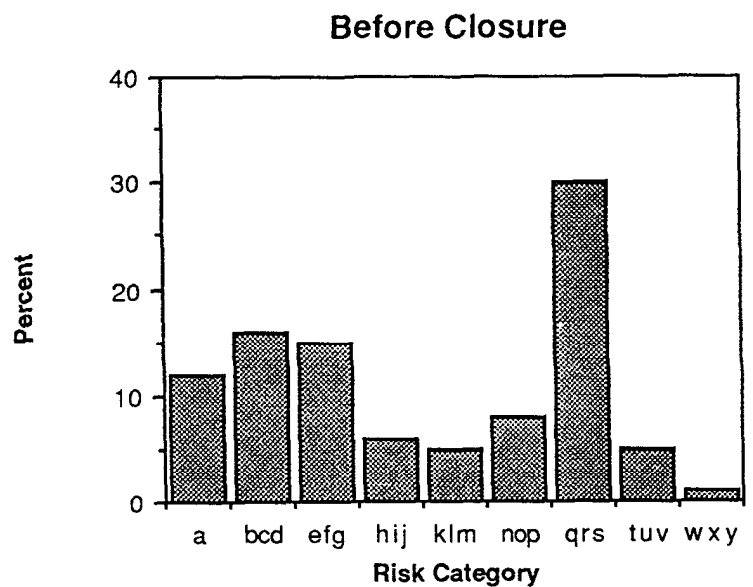


FIGURE 4.3

SUBJECTIVE HEALTH RISK



Annual Risk of Death:

a = no risk

b = one in 9 million

f = one in 100 thousand

j = one in 10 thousand

n = one in one thousand

r = one in one hundred

v = one in ten

distribution in Figure 4.3(a). Other researchers have also observed a similar bimodality. As Slovic, Fischhoff, and Lichtenstein (1981) have noted, "people often attempt to reduce the anxiety generated in the face of uncertainty by denying the uncertainty, thus making the risk seem so small it can safely be ignored or so large that it clearly should be avoided." It therefore appears that bimodality of risk judgments characterizes responses to low probability risks: some people "edit" the risk away while others may exaggerate its importance.

Figure 4.3(b) shows the frequency distribution of beliefs about risk after closure of the site. The bimodality, although present, is much less pronounced than for judgments before closure, and the judgments of risk are in general lower.

For purposes of subsequent analysis, we constructed a new binary health belief variable that indicated the mode for each respondent's judgment of risk. The dividing line between the two modes is the letter L on the risk ladder, approximately  $5 \times 10^{-4}$  per year. Approximately 51 percent of the sample was in the high health risk mode before closure.

#### 4.5 Comparison of Expert and Resident Health Risk Beliefs.

The epidemiological studies have found virtually no health risk, so from that perspective almost all the respondents believe the health risk to be higher than the expert estimate. If we use the calculated risk for the one extreme recorded exposure of vinyl chloride as an upper bound for the scientific risk ( $1.67 \times 10^{-5}$ ) then the half of the sample in the upper health risk mode (the cut point equals  $5 \times 10^{-4}$ ) overestimates the health risk by at least one order of magnitude. The bimodality also implies that whatever the true risk, approximately half the respondents seriously misestimate

that risk. Either those in the high mode are greatly overestimating the true risk or those in the low mode are greatly underestimating the true risk. For all these reasons it is reasonable to include that the subjective health risk beliefs for many respondents differ substantially from the expert judgments.

A comparison in Figure 4.3 of the frequency distributions of beliefs of risk before and after closure of the site also suggests another way in which the beliefs of residents are inaccurate. There was a substantial believed reduction in health risk as a function of site closure. However, at the time of closure OII had already stopped accepting hazardous material and whatever toxic chemicals may have emanated from the site before closure would be just as likely or even more likely to emanate from the site after closure. Thus the aggregate reduction in subjective judgments of the health risk cannot be accurate.

#### 4.6 A Model of Subjective Beliefs About Risk.

The great variation in estimates of subjective health risk suggests that those judgments must be due in part of psychological and sociological factors other than a perception of the true health risk. It is therefore interesting to model subjective health risk judgments using psychological and sociodemographic variables assessed in the survey. Potential variables for inclusion in the model are described below in conceptual groups.

Experiential Variables. The more that experience has made one aware of the potential health problems from the landfill, the higher one's estimate of the health risk is likely to be. Thus, the model includes variables which assess awareness of the potential problem through several sources. In particular, the model includes respondent awareness of media

attention to the problem and perception of odor from the site as experiential variables. Also included is geographic distance to the site as a proxy variable for other experiential effects. Presumably, those respondents who live near the landfill will have had more visual reminders of the potential health hazards.

Sociodemographic Variables. Judgments of health risk may vary as a function of various sociodemographic variables. For example, older respondents will have necessarily survived a number of hazards and may therefore place the present landfill risk in a different context than a younger respondent who is raising children. Although we do not have specific hypotheses about the risk effects of these variables, we examine income, education, age, gender, number of children living at home, occupation, and ethnicity as possible components in a model of health risk judgments. It is possible to examine ethnicity because of the high proportion of Asian-Americans in this sample.

Site Closure Variable. As already noted, the mean judgment of the health risk was lower after closure of the site to further dumping. We therefore include an indicator variable to mark whether the estimated health risk is for before or after closure of the site.

Health Risk Dependent Variable. The strong bimodality in the distribution of health risk judgments suggests that the error from any model of those judgments would be unlikely to meet the usual distributional assumptions necessary for statistical tests. Also, we are more interested in the correlates of which mode a respondent is in rather than the minor variation within each mode. So, the subjective health risk scores were recoded to reflect mode: those in the upper mode received a score of 1 and

those in the lower mode received a score of 0. This recoding does not solve all the problems with the error structure because ordinary least squares (OLS) analysis of binary data can be problematic. We therefore perform both OLS and PROBIT analysis. Computer limitations constrained the number of variables possible in the probit analysis with this many observations, so we used OLS to screen variables for inclusion in the probit analysis.

#### 4.6.1 Model for Health Risk Judgments.

Table 4.1 gives the partial regression coefficients and their associated t statistics for both the OLS and PROBIT analyses. Both analyses produced exactly the same conclusions. We therefore discuss the results in terms of the OLS regression because it is generally easier to understand. It should be remembered that the statistical tests are for partial regression coefficients. That is, the test asks whether the given variable reliably explains a portion of the variation in health risk after controlling for all the other variables included in the model. With covariation among the predictor variables this can produce conservative conclusions about the importance of a variable.

As expected, the site closure variable is a statistically significant component of the model even after controlling for all the other variables. All three experiential variables had significant coefficients. Odor in particular stands out as an important predictor of subjective health risk. Distance from the site was also a significant predictor after controlling for odor perceptions. Thus, there must be other perceptions or concerns associated with distance besides the perception of odor which affect judgments of health risk. Frequency of exposure to media attention about the site also predicted increased health risk judgments.

TABLE 4.1

Regressions Explaining Subjective Health Risk  
Before Closure of the Operating Industries Inc. Landfill

<u>Variable Name</u>	Mean	Std. Dev.	Estimated Coefficients (t in parentheses)	
<b>DEPENDENT VAR.</b>			<u>OLS</u>	<u>Probit</u>
Subjective Health Risk (1 if in upper mode 0 if in lower mode)	0.415	0.49		
<b>INDEPENDENT VAR.</b>				
Constant			0.57 (1.78)	-0.67 (-2.26)
Closure Dummy Var. (1 before closure) (0 after closure)	0.52	0.50	0.094 (2.77)	0.29 (2.681)
<u>Experiential Var.</u> Frequency of hearing or reading about OII problems.	4.11	0.96	0.037 (2.16)	0.14 (2.61)
Perceived odor problems	16.45	14.35	0.013) (9.83)	0.040 (9.44)
Distance from site (blocks)	11.50	7.07	-0.0083 (-3.53)	-0.028 (-3.78)
<u>Socio-Economic Var.</u> Number of people under 18 living in house	0.91	1.05	0.047 (2.64)	0.12 (2.27)
Age of respondent	48.48	12.63	-0.0035 (-1.98)	-0.0097 (-2.14)
Income	47.631	22,038	0.354E-6 (0.45)	-
Sex of respondent (0 female) (1 male)	0.79	0.41	-0.12 (-2.91)	-0.31 (-2.52)
level of education (1-9)	6.34	1.91	0.0019 (0.18)	-
<u>Occupation Var.</u>  (Sales or Managerial = 1; service. Repair. Labor, or Farm/Fishery = -1; Retired = 0)	0.39	0.84	-0.00078 (-0.038)	-
<u>Ethnic Var.</u>  #1 (Caucasian = 2; Asian or Hisp. = -1)	-0.17	1.28	0.00076 (0.056)	-
#2 (Caucasian = 0; Hispanic = -1; Asian = 1)	0.22	0.79	0.030 (1.45)	-
Sample Size			762	
R <sup>2</sup>			0.282	
Likelihood Ratio Test				238.87

It is important to recognize that a cross-sectional survey such as this must necessarily suffer from causal ambiguity. For example, we have included frequency of exposure to media attention as a predictor of health risk judgments. However, it might be the case that someone who becomes concerned about the health risks will pay more attention to and seek out media reports about the problem. Similarly, someone who is concerned about the health risk may be more alert for the odor problem and hence report having experienced it a greater number of times.

It is interesting to ask whether sociodemographic variables can explain variation in health judgments over and beyond the variation attributable to the more direct experiential and perceptual variables. Having statistically controlled for the experiential variables, any effects of sociodemographic variables represent largely attitudinal effects. The two socioeconomic status variables of income and education had inconsequential effects. Thus, it is not true that those who had more to lose economically were more concerned about the risk. However, the number of children living at home was a significant predictor so in that sense those who had more to lose were more concerned about the risk. Age of respondent is obviously correlated with having children living at home but age predicted variation over and above that variable. The direction of the effect is that younger people thought the hazards of the site were more risky. Gender also made a significant difference with females believing the site is more risky than did males. A coded variable contrasting managers and sales people against service, labor, and repair occupations (those in the latter group are presumably exposed to more on-the-job risks) indicated no differences in risk judgments. Similarly, two variables coding ethnic group (one

contrasting Caucasians with Asian-Americans and Hispanics and one contrasting Asian-Americans with Hispanics) yielded no significant differences. There are, therefore, no suggestions in this sample of any occupational or cultural differences in the evaluation of risk.

A reasonable model of judgments of the health risks associated with the OII Landfill site includes the following components: site closure, media exposure, odor, distance to site, number of children living at home, age, and gender. This model accounts for approximately 28 percent of the variation in the coded health risk variable. This is substantial for a model of this type, especially given that the dependent variable is binary. What does the model mean? First, the importance of the perceptual odor variable above and beyond the other variables is striking. It is easy to speculate that without vivid, perceptual cues from the site, risk judgments would be greatly reduced. More important than the specific pattern of significant coefficients, however, are the following conclusions: (a) there is great variability and bimodality in judgments of health risks; (b) many respondents have inaccurate beliefs about the extent of the health risk; and (c) the variation in health risk judgments is not random but can be related to systematic differences among respondents.

#### 4.7 Real Estate Markets Around OII.

In this section we analyze the role of perception and risk judgments on the real estate market in the area around the OII Landfill. However, in analyzing the real estate market near the OII Landfill, individual perceptions and attitudes are of less importance than the collective perceptions and attitudes of individuals residing in neighborhoods in the vicinity of the waste site.

Although residents may well be willing to sell at a price adjusted

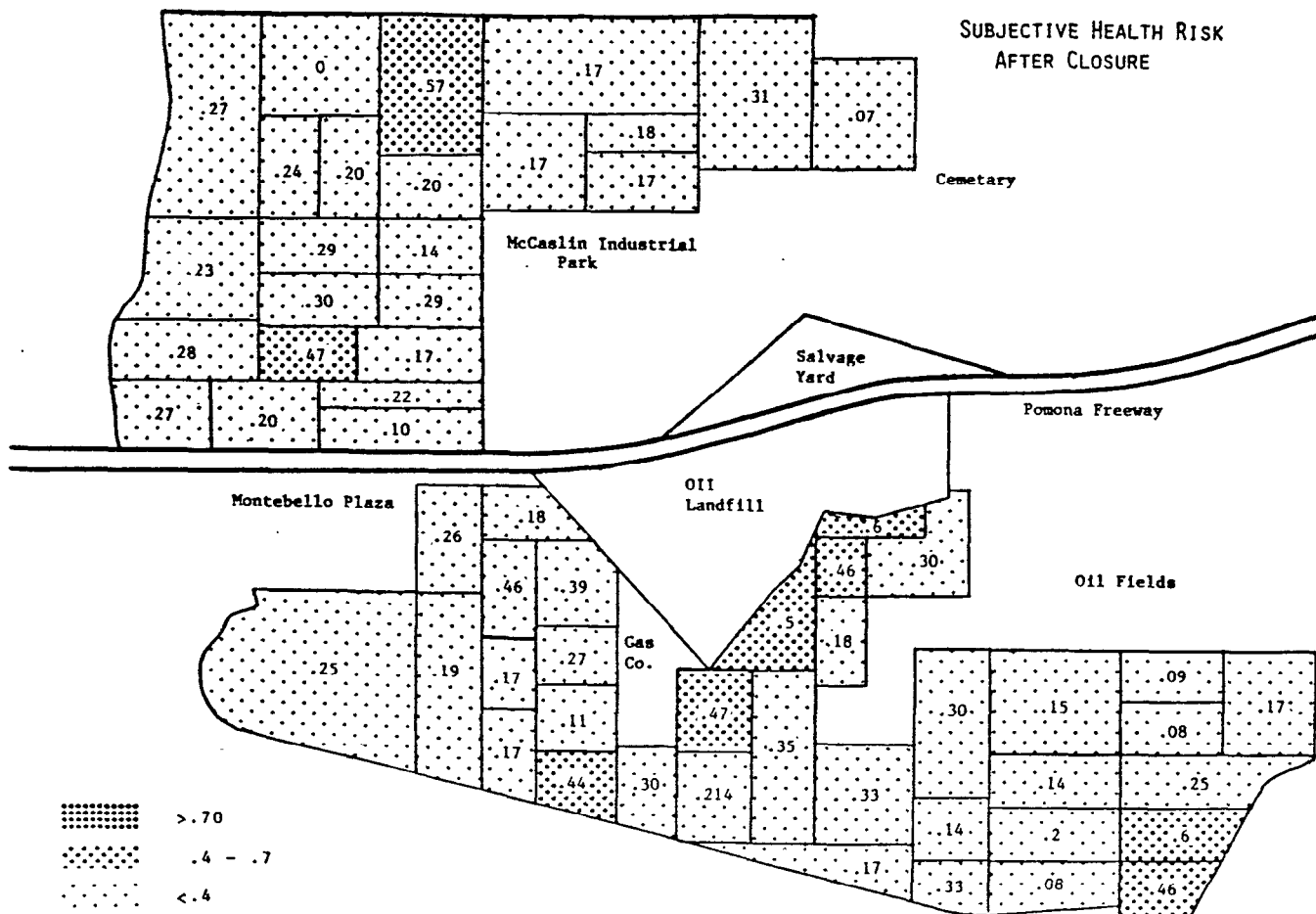
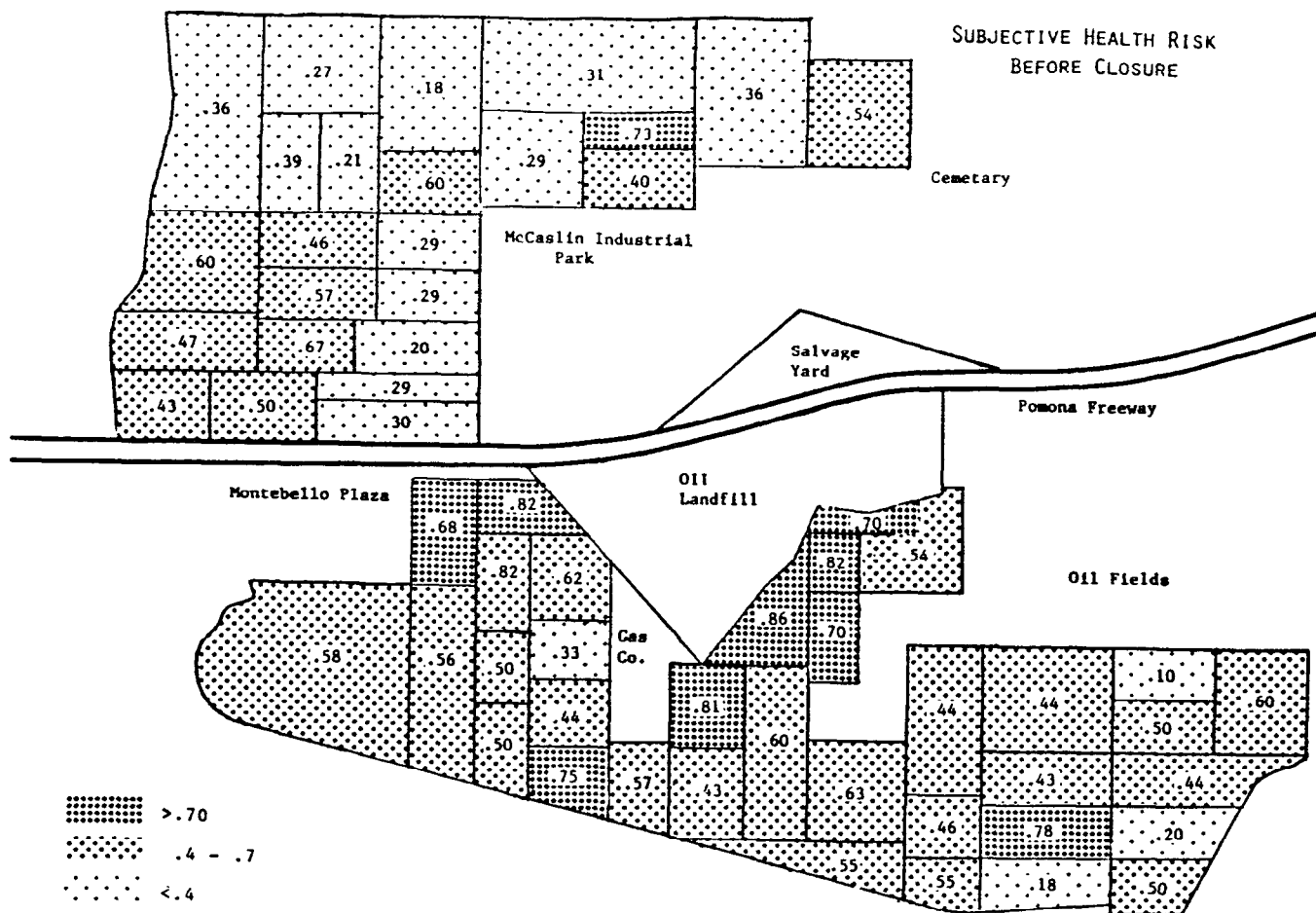
downward by their willingness to pay to avoid any subjective risk associated with proximity to the OII Landfill, they are likely to list homes, after consulting a realtor, at the "going" market rate. Thus sellers will attempt to obtain a price higher than their actual willingness to sell. In effect, sellers will try to obtain some consumer surplus as is normal in all competitive markets. In fact, in a neighborhood the supply curve will be shifted to the right to the extent that homeowners within a neighborhood feel that the OII poses a risk. Thus, the greater the percentage of homeowners in a neighborhood who feel that the OII Landfill poses a threat, the further the supply curve will be shifted to the right relative to an initial supply curve that assumes no homeowners in the neighborhood feel threatened by the site. Thus, the observed price for homes in a particular neighborhood will fall as more homeowners in a neighborhood feel threatened. Unfortunately, we have no information on the subjective risk beliefs held by potential purchasers who make up the demand curve; but note that sixty-two percent of recent purchasers were not aware of the site when they bought their homes, despite local requirements for information disclosure to new buyers. Those that were aware may, of course, have lowered their offered bids, shifting the demand curve downward to the left, causing a further decline in observed prices. Since we have no data on subjective risks by neighborhood for prospective purchasers, we must assume that the subjective risk of residents measured for each neighborhood around the OII Landfill can proxy for that of purchasers in our reduced form estimated property value equation. Thus, we focus on the development of neighborhood rather than individual measures of perceived odor problems, subjective health risk and explosion risk. In order to

provide the spatial distribution of the key variables for the property value study, we plotted households responding to the survey on an aerial photograph of the area. Using the aerial photograph, the area around the site was divided into neighborhoods with about 10 to 15 data points in each neighborhood. Having identified responses within a given neighborhood, perception characteristics can be attributed to homes sold in neighborhoods and used as independent variables in the property value study. Figure 4.4 shows how judgment of health risk is spatially distributed around the site both before and after closure of the landfill. The number used for each neighborhood represents subjective health risk as the fraction of residents who lie in the upper mode of the bimodal distribution of risk perception. Therefore, values of the subjective risk measure will fall between 0 and 1, with neighborhoods having a high number of upper mode residents approaching 1 and neighborhoods with a low number of upper mode residents falling near 0. The Figures generally show that in neighborhoods closer to the landfill, the fraction of residents with a high level of health risk perception is larger. In the discussion that follows, the effects of perceptions and subjective judgments on property values is explored.

#### 4.7.1 Property Values Near the OII Landfill.

Residents in the vicinity are troubled by a decline in the value of their property that they believe is caused by the location, size and the presence of hazardous wastes at the OII Landfill. The effects on property values are further aggravated by intensive media coverage that has tended to focus on the possible risks and the presence of odor problems, which has appeared to have strongly influenced perceptions and subjective judgments within the area.

FIGURE 4.4



The Hedonic Price Method (HPM) attempts to value certain environmental amenities (or disamenities) by studying markets in which an environmental attribute may be captured (See Rosen 1974). In this case, the value that people hold for avoiding hazardous waste problems may be proxied by relative declines in the real estate market near the hazardous waste site. The model postulates that the value of a home is a function of the quantity and quality of certain physical attributes of the home and neighborhood including perceived environmental conditions. By estimating a reduced form property value equation, the relative role of each of the factors can be determined, including the relative importance of perceived environmental conditions in determining the value of homes.

We obtained property value data through a real estate information network. These data included home sales information and characteristics from August 1983 through November 1985 (which spans the closing of the OII Landfill late in 1984). Combining current property sales data from secondary sources with current perception and subjective judgment data from the survey has made it possible to construct a hedonic model to explore how perceptions and subjective judgments affect property values. As discussed above, subjective risk and perceived odor data were grouped into neighborhood variables.

Neighborhood subjective risk and perceived odor data are available for both before and after closure of the OII Landfill. Therefore, there arises a question about the timing of the shift from before to after closure risk judgments and perceptions. It was hypothesized that a lagged effect would be present and that before closure perceptions would persist (at least in terms of buyers moving to the area) past the date that the OII

Landfill actually closed. A six month lag was used, evenly splitting the period between the two points in time for which subjective risk and odor perception information was obtained. The OII Landfill officially ceased accepting additional wastes on the last day of October 1984, but home sales during the first 6 months following the closure were assigned the neighborhood subjective risk and perceived odor values that were present before closure. A linear functional form was used in specifying the equations because of the ease in interpreting the coefficients and because results obtained from alternative log forms were not significantly different.

#### 4.7.2 Property Value Model.

In the secondary data set, 179 home sales were identified within the area near the OII Landfill during the 28 month period. The data was pooled in order that information on both before and after closure could be included in the analysis. Table 4.2 shows the results of four model specifications corresponding to the inclusion of subjective health risk, subjective risk from explosion, perceived odor and all three, respectively. The results suggest that subjective health risk may be the primary factor causing a decline in property values. With a coefficient of \$-13,719 and a t-value of -1.80, it appears that the effect of subjective health risk is both significant and non-trivial. Neither subjective explosion risk nor perceived odor appears to be significantly contributing to the fall of property values. Considering the change in the size of the coefficient on subjective health risk from the first specification to the fourth, it appears that the multicollinearity between subjective health risk, subjective explosion risk and perceived odor is sufficient to cause

TABLE 4.2

HEDONIC PROPERTY VALUE REGRESSION  
For Homes Near the Operating Industries Inc.  
Landfill in Monterey Park, California

Variable Name	Mean	Std. Dev.	Estimated Coefficients (t in parentheses)			
			1	2	3	4
Dependent Var. Sale Price (\$)	135,863	35,253				
Independent Var. constant			96,231.1 (8.26)	90,674.9 (7.72)	95,711.9 (7.65)	95,560.0 (7.70)
Subjective Health Risk <sup>1</sup>	0.41	0.20	-13719.8 (-1.80)	-	-	-22051.7 (-2.07)
Subjective Risk From <sup>2</sup> Explosion	8.43	3.26		-5.66 (-0.014)		865.8 (1.53)
Perceived Odor <sup>3</sup>	17.43	7.20	-	-	-184.1 (-0.95)	-88.9 (-0.35)
Date of Home Sale by month (08/83 - 1;08/85 - 25)	15.1	7.7	491.8 (2.70)	647.2 (3.83)	581.0 (3.29)	464.7 (2.52)
Area of Home (ft <sup>2</sup> ) (X - SqFt)	-0.041	475.5	50.63 (9.04)	49.61 (8.81)	50.61 (8.87)	51.09 (9.00)
" " " (ft <sup>2</sup> ) <sup>2</sup>	224,807.3	262,400.7	0.021 (3.83)	0.0194 (3.61)	0.0191 (3.56)	0.019 (3.68)
Number of bathrooms	2.0	0.64	488.0 (0.12)	1,653.6 (0.41)	1,062.7 (0.27)	538.5 (0.13)
Year Home Built (i.e., 77, 84, 56)	58.8	9.8	523.4 (2.82)	454.0 (2.44)	457.7 (2.51 )	499.3 (2.66)
Swimming Pool (0 if no pool; 1 if pool)	0.17	0.38	13,354.0 (4.00)	12,564.4 (3.76)	12,614.2 (3.79)	13,153.0 (4.19)
Scenic View From Home (0 if no view; 1 if view)	0.07	0.26	1,554.3 (0.31)	1,636.8 (0.33)	1,633.6 (0.33)	1,145.4 (0.23)
Fireplace in Home (0 if no fireplace; 1 if fireplace)	0.45	0.50	-603.4 (-0.21 )	-1,219.5 (-0.42)	-883.9 (-0.30)	-502.2 (-0.17)
Proximity to Highway (1 if within 2 blocks; 0 otherwise)	0.06	0.24	-12,173.8 (-2.35)	-10,831.3 (-2.09)	-10,776.1 (-2.09)	-12,331.5 (-2.36)
R <sup>2</sup> sample size	179		0.802	0.798	0.799	0.805

<sup>1</sup>This variable represents the fraction of respondents within a neighborhood who responded to survey Question 12 with a subjective health risk greater than 5 deaths in 10,000 (atop L). Homes sold prior to May 1985 were assigned a value corresponding to before closure subjective risk, and home sold after May 1985 were assigned the Corresponding risk value for after closure subjective risk.

<sup>2</sup>This variable represents a logarithmic scale from 1 (no risk) to 26 (certain risk) taken from responses to question 13 of the survey. Each neighborhood was assigned the mean value of responses within that neighborhood with home sold prior to May 1985 receiving the mean before closure value and home sold after May 1985 receiving the mean of the after closure value.

<sup>3</sup>This variable represents the product of frequency and intensity of perceived odor problems from responses to Question 11 in the survey. The resulting scale goes from 1 (very small problem) to 50 (very great problem) with homes sold prior to May 1985 receiving the mean neighborhood value before closure and homes sold later receiving the mean neighborhood value after closure.

sign changes in the coefficient on subjective explosion risk and to alter the coefficients on odor and subjective health risk. However, it is clear from the individual specifications that odor and risk from explosion are much less significant in explaining the observed property value decline. Other significant variables in the model include the date of home sale, the area of the home, the year the home was built, presence of a swimming pool, and the proximity of the house to the Pomona freeway.

#### 4.7.3 Assessment of Total Subjective Damages Around the Site.

The coefficient on the effect of subjective health risk on property values, as identified in the econometric model, is \$-13,719. To arrive at a total assessment of property value damage for the area, the total number of homes in each neighborhood cell was identified from an aerial photograph. This number was multiplied by the fraction of homes with a high subjective risk judgment in each neighborhood and by the coefficient on subjective health risk (\$-13,719) and then summed over the sixty neighborhoods. This same procedure was followed using the after closure fraction of residents in the upper mode of subjective risk judgment to arrive at an after closure assessment of damages. The subjective benefits of closing the landfill amount to the difference between the before and after subjective damage assessments. The before closure estimate of subjective damages amounted to over \$27 million for the 4100 homes near the site. After closure subjective damages amounted to \$13 million resulting in a subjective benefit of closing amounting to \$14 million.

These figures represent the magnitude of the real economic damages that residents in the area must bear because of property devaluation in the area of the OII Landfill. These figures also indicate the effect that closing the site may have had on property values and also suggest the magnitude of

the potential benefits of better risk communication if, residents and potential home buyers could be convinced that the risk is truly small.

#### 4.8 Changing Subjective Health Risk Judgments.

The evidence suggests that although the damages that have occurred to property values are real, the damages depend on subjective health risk beliefs which may change in response to factors other than objective risks. With effective risk communication measures and the further reduction of negative perceptual cues, property values may show a further recovery from these subjective damages. The relevant question becomes: Does mitigation of subjective damages require a complete and costly site cleanup or can other measures such as attempts to communicate objective risks along with more limited action to clean up the site provide a satisfactory solution?

It appears that large benefits can be obtained by changing subjective risk beliefs by communicating objective risk information to the public living near Superfund sites, and that these benefits may substantially exceed those from even eliminating objective health risks that may exist. In fact, community agreement that the problem has even been adequately addressed seems unlikely as long as current subjective risk judgments prevail. We concur with the conclusion of Covello, Von Winterfeldt and Slovic (1986) who state

... the literature specifically focused on risk communication is relatively small. Substantial progress has been made on some topics, such as psychological research on public perceptions of risk, but large gaps exist in our understanding of virtually every issue relevant to risk communication.

The importance of better risk communication is well understood but the

methods are lacking. In a study of public perception and response to EPA warnings concerning the risks of ethylene dibromide (EDB), Sharlin (1986) analyzed and compared what EPA was trying to tell the public about the risks of EDB to the information the public actually received through the media about these risks. He found vivid contrasts between the public's view of the health risks and the EPA's aggregate statistics on health risks. The extent and nature of this contrast is an area that needs further exploration.

Two main conclusions emerge from the OII study results: (a) subjective health risks are likely to be overestimates of the objective risks and (b) the overestimated subjective health risks are associated with significant property value losses. In many respects it is similar to the situation described in Chapter 1 where a warning was issued for possible volcanic activity. In several instances the overreaction to such warnings has resulted in economic losses due to property devaluations that far exceeded the expected economic losses. When, as in the case of the OII Landfill, total damages from the overestimates of risk are on the order of \$27 million, a program designed to change subjective estimates of health risks can easily be cost effective.

Figure 4.5 illustrates a schematic framework that integrates the model of subjective health risk with the model of property values. The left side of the Figure represents a model for subjective health risk estimates of individual survey respondents. The right side of the Figure shows the factors impinging on property values. (The property value modeling is necessarily an aggregate analysis because property value changes could be linked with subjective health risk variables only at the neighborhood

```
graph TD; PC[Perceptual Cues] --> SHR[Subjective Health Risk]; SHR --> PV[Property Values]; SD[Sociodemographics] --> SHR; PC[Property Characteristics] --> PV;
```

**Perceptual Cues**

- Odor
- Distance to Site
- Media Attention
- Site Closure

**Subjective Health Risk**

**Property Values**

**Sociodemographics**

- Age
- Children
- Gender

**Property Characteristics**

- Sq Ft.
- Proximity to Highway
- Age of Construction
- Etc.

level.)

The modeling of subjective health risk judgment points to two components for possible intervention: perceptual cues and attitudes associated with sociodemographic variables. Of the two, psychological research shows that perceptual cues are much easier to change than attitudes. Managing the perceptual cues which serve to remind people about the risk can be very effective in reducing risk estimates to more appropriate levels. The management of perceptual cues would involve such things as reducing odor, reducing visibility of the site using plantings or screening, reducing activity at the site (e.g., reducing number of trucks entering and leaving), and reducing sensational media coverage of the site. These are not necessarily easy to implement. Some of these strategies such as reduced media coverage can only be recommended, not mandated. Others such as reducing odor and reducing activity are difficult or impossible to implement short of closing the site. However, if such reductions can be obtained, the management of perceptual cues can have dramatic effects. If subjective health risks for a hazardous site are overestimates of the objective risk, then the perceptual cues about the risk should be managed as extensively as possible. The economic savings obtained by correcting and/or avoiding inappropriate property devaluations are likely to be large.

After major changes in the perceptual cues associated with closing the site, many people maintained high risk estimates. These high risk estimates translate via the property value equation into an estimated remaining loss of about \$13 million. This residual loss is due partly to perceptual cues that cannot be easily modified (visibility of the site

and the methane plant) and to risk attitudes. Given that further modifications of perceptual cues are probably impossible, further reductions in subjective health risks and their associated effects on property values could only be achieved by credible, effective communications about the objective risk.

Risk attitudes and beliefs should be changed if health risks are truly small. Changing attitudes is notoriously difficult and there are several factors which compound the problem in this context.

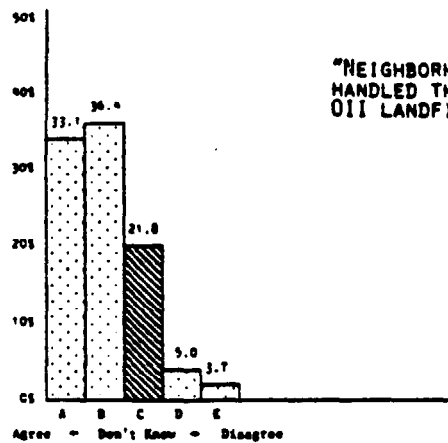
First, many psychological studies (see Tversky and Kahneman 1974; Slovic, Fischhoff, and Lichtenstein 1977) have shown that most people have trouble understanding probabilistic information in general and expert assessments of risk in particular. To be understood, expert assessments are best communicated by comparing new risks to better known risks such as smoking and X-rays rather than presenting technical measures such as mortality rates for a given exposure. No information of the appropriate type of risks has been provided to residents near the OII Landfill.

Second, to be effective, risk communication must come from credible sources. Figure 4.6 shows how credibility is perceived among a few of the important actors at the OII Landfill. Residents in the area perceive that neighborhood groups have acted the most responsibly with the media also receiving a favorable response. The EPA, however, was not as well perceived, and is now unlikely to be viewed as a credible source since residents ranked EPA nearly as low as the operators of the OII Landfill in terms of how "responsibly" the agency had dealt with problems at the site.

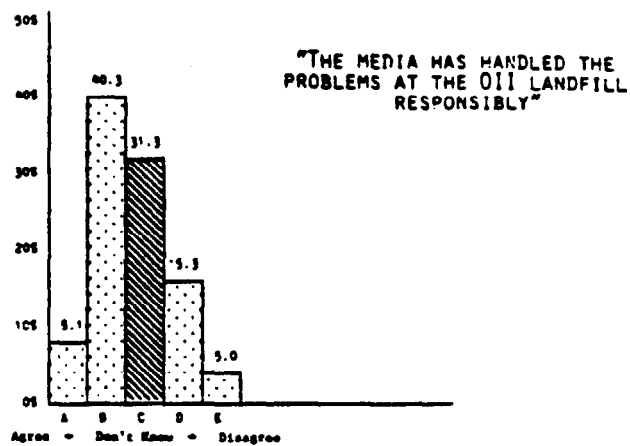
Third, even though it has not been especially effective, much more is known about increasing subjective risk judgments (e.g., risks of smoking,

FIGURE 4.6

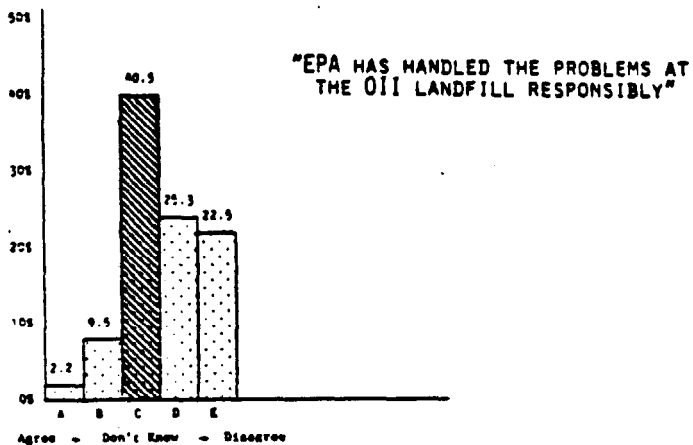
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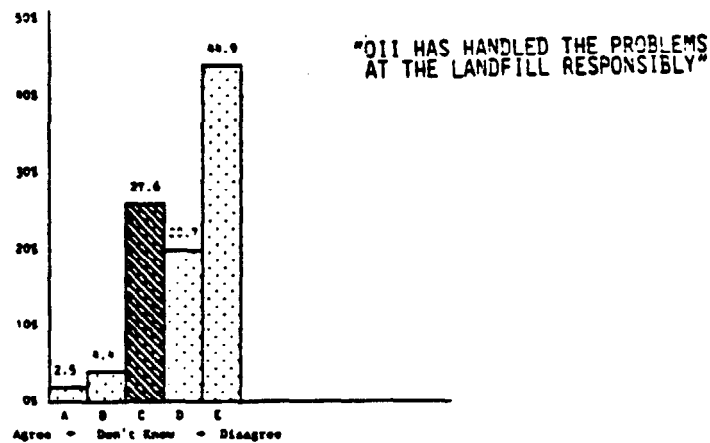
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% of Sample



% of Sample



A Agree strongly  
B Agree  
C Don't know  
D Disagree  
E Disagree

A Agree strongly  
B Agree  
C Don't know  
D Disagree  
E Disagree strongly

risks of not using seat belts) than about decreasing risk judgments.

Fourth, communications about issues with a high affective component (e.g., the emotionality surrounding a landfill hazard issue) are often misinterpreted and misunderstood. For these and other reasons a quick fix via risk communications for the attitudinal inflation of risk estimates is improbable. The potential elimination of approximately \$13 million in property value losses would, however, justify considerable efforts to change subjective risk estimates to more realistic levels.

#### 4.9 Conclusions.

While changing risk attitudes will not be easy, there are several studies which suggest some optimism. Hammond and his colleagues at the University of Colorado (see Hammond and Adelman, 1976; Hammond et al. 1984) have been successful in reducing disagreements about risk among experts and then communicating the resulting judgment about the risk to the public. Examples include public concern about a new police handgun bullet and about possible plutonium pollution from a nearby facility. Characteristics of these successful efforts to reduce overestimated risks share the following attributes.

First, a citizen panel (such as the HELP group) selects a group of independent scientists to evaluate the risk. The danger at this stage is that, all too often, the citizen's panel will want to become technical experts themselves in order to make their own risk judgments. Their proper role is representing community values and the procedure generally works best if they stick to that.

Second, the group of scientists uses standard scientific and scholarly procedures (e.g., references to referred journal articles, development and defense of mathematical equations producing the risk estimate) to resolve

their differences. Also of use in this stage are psychological techniques for studying judgments and techniques that help identify issues of disagreement that need resolution. Contrary to the danger in the first stage, the danger here is that the scientific experts will make action recommendations for the community. Such recommendations necessarily are based on both risk judgments, which the technical experts should make, and assumptions about community values, which the technical experts should not make.

Third, once agreement on the magnitude of the risk is obtained (and surprisingly such agreement is almost always obtained), the results are communicated to the public via the local media. What is communicated to the public is the experts' conclusion that the risk is either low or high and a comparison of the risk to known, widely-accepted risks. For example, comparing the danger of plutonium emissions to smoking or hospital X-rays.

Although the above approach is not a panacea, it does offer a reasonably inexpensive means for attempting to reduce subjective health judgments, which due to attitudes, overestimate the true risk. Given the magnitude of potential benefits, the past success and relatively small cost of such procedures justifies their use in an attempt to change subjective health risks.

## CHAPTER 5: RISK COMMUNICATION GUIDELINES

### 5.1 Introduction.

Proper communication of the level of risk for a particular Superfund site is a crucial component of successful community relations. Poor risk communication leads to confusion among community members as to the appropriate level of concern about the hazards of a site and can also produce unnecessary disagreement within the community. Thus, poor or inadequate communications about risk can make an already difficult community relations problem even more difficult. This chapter describes characteristics of good risk communication; all EPA and contractor personnel should always have these characteristics in mind when developing any communication about the hazards of a site. This chapter also makes the important point that there are many indirect ways--for example, the appearance of the site to community members--in which risk is communicated. EPA personnel must carefully monitor those indirect communications and make sure that technical contractors do not inadvertently communicate inappropriate messages about risk levels through their actions. The chapter concludes with a series of specific recommendations for communicating information about the risks of Superfund sites.

There are numerous situations in which the level of risk must be communicated to a community in which a Superfund site is located. Successful risk communication cannot be accomplished unless all aspects of community relations are handled with care. Thus, all the guidelines from Community Relations in Superfund-A Handbook apply to risk communication as well. We do not repeat those guidelines here but instead describe some principles for

presenting information about levels of risk, principles that apply to all community relations situations.

It cannot be overemphasized that good risk communication, as all good communication, is a two-way process. Community relations personnel must learn from members of the community their concerns and their beliefs about the risk associated with a particular site. Community relations personnel have an important role to play between the technical experts and the community. Risk assessments developed by off-site experts sometimes respond only to technical characteristics of the site while unintentionally ignoring some community concerns. For example, consider a site from which emits an unpleasant odor. A technical expert might know immediately that the odor was not harmful and so ignore it completely in a technical report, instead concentrating on chemicals, the names of which are probably unfamiliar to the general public, that might be leaking from the site. The community would obviously be aware of and concerned about the possible health consequences of the odor so a risk communication that did not explicitly address the odor problem would be inadequate and unacceptable to the community. Thus, risk communication must address all the concerns of a community, whether or not the technical experts see those concerns as important.

It should be stressed that guidelines in this chapter apply to all risk communication situations. Research has so far shown that the best ways of communicating risk are the same for experts and community leaders as for the general public. Thus, the same communications should be given to everyone. Not only is this more efficient, but it also avoids the potential problems that could be created by attempting to give different information to different

groups in the same community.

## 5.2 Credibility.

No communication enterprise can be expected to be successful if the source of the information has not established credibility. If the source of risk information is not credible, then it will have little chance of being accepted. Community concerns may in fact get exaggerated because the dubious attitude toward the source will extend to the risk communication. Obviously, this situation could escalate, causing permanent damage to community relations. There are several steps that can help in establishing credibility:

1. Neutral, well-regarded experts should be appointed to assess the risk. Scientists in the appropriate fields are especially good candidates.
2. These experts should report to a credible level of government or to a credible group of government officials. Often the most local level is most credible to the community, but this will vary with the site. If no credible level of government exists, a citizen committee of community leaders can be used.
3. The credible government officials or citizen committee should release the risk information to the general community, including the press.

Information should be released in a consistent manner. Care must be taken with the news media, especially, who can inadvertently cause distortion in the risk perception by presenting inconsistent information and distorted perceptions (please see Section 5.5).

The remaining sections of this chapter will address how the level of risk of a site should be expressed to achieve the best understanding as well as some principles of risk perception that are important for Superfund and contractor personnel to know when preparing information releases, developing a

community relations plan, or planning on-site activities.

### 5.3 Overview of Risk Communication Principles.

There are a number of important factors that need to be considered in communicating risk; each factor will be addressed in detail in the remaining sections of the chapter. The major components in the formation of community risk beliefs for a Superfund site are:

- (5.4) Physical reminders around the site,
- (5.5) News media presentation of the risk,
- (5.6) Community characteristics,
- (5.7) Reaction to low-level risks,
- (5.8) Characteristics of the risk, and
- (5.9) The framing of losses and gains

The Chapter concludes with

- (5.10) Use of example risks, and
- (5.11) Recommendations.

### 5.4 Physical Reminders.

Physical reminders of the site provide an indirect but very powerful and important means of communicating levels of concern to the community. Heavy truck traffic to and from the site, heavy chain-link fences with large imposing warning signs, odors emitted from the site, discoloration of water, and on site workers wearing protective "space" suits are all examples of physical reminders that implicitly send a message to the community about the level of risk at the site.

Community relations personnel should make a careful inventory of all the physical reminders at a particular site. For those physical reminders that are modifiable, the community relations officer should try to ensure that each

physical reminder is appropriate for the actual level of risk. Regional contractors as well need to be aware of physical reminders. For example, if being at or near the site is not actually harmful then a more discrete fence such as hedging may be preferred to a heavy chain-link fence with large red warning signs. Conversely, if the site is an old, familiar spot in the community and the citizens have become inappropriately careless about the site, then an imposing fence with many warning signs will be critically important.

For those physical reminders that are not modifiable, the community relations officer must ensure that the community has the proper information necessary to understand the meaning of the physical reminder in terms of the level of risk. Many physical reminders are very misleading indicators of the true level of risk. As an example, in Colorado, iron contamination from an old mine that is now a Superfund site caused a poor taste and red color in the drinking water of several downstream communities. Although the poor taste and discoloration were undesirable and clearly needed to be remedied, drinking the water was, in fact, not likely to be harmful. However, the taste and color served as physical reminders of the iron contamination and made many residents fearful about drinking the water. A successful community relations effort would have provided residents with the necessary information to understand that the taste and discoloration were undesirable but not harmful.

The community relations officer must also be particularly careful to alert the community to any changes in the physical reminders. Unannounced changes in the physical reminders almost always send a more extreme message about the level of risk than is appropriate. For example, if decontamination workers in protective clothing appear at a site unannounced, then the level of community concern will immediately increase to very high levels. Even if

the arrival of such workers is announced, levels of community concern will increase but the level of concern will generally be more consistent with the actual level of risk than if no advanced preparation had been done.

#### 5.5 News Media Presentation of Risk.

The news media provide much information concerning the risk level of a site. For many citizens the newspaper, radio, and television are their primary sources of information about the site. As in any good community relations plan, it is essential that the news media have advance announcement of all activities at the site. Also, the community relations officer must provide them with any background information that might be necessary to help them and the public to interpret the reports from technical experts.

The community relations officer should be alert to a problem that often arises in communicating risks to the public through the news media. It often happens that someone very concerned about the site who is not a technical expert becomes an unofficial spokesperson for the group of citizens who are very concerned. This person is always available for interviews with the news media and is often eager to make statements about what they believe about the risk posed by the site. To balance the sometimes exaggerated risk estimates that may result, consistent information from credible sources (see Section 5.2) should be regularly available to the news media. It is of course important that the credible source be independent of the control of the Environmental Protection Agency.

#### 5.6 Community Characteristics.

High levels of concern about risks are often associated with certain community and individual characteristics. Knowledge of these characteristics can help Superfund personnel and contractors anticipate and prepare for

difficult risk communication situations, situations in which unwarranted conflict may arise. This section identifies a number of personal and demographic characteristics that are often associated with high levels of concern.

An obvious characteristic of great importance is proximity to the site. Residents living near a hazardous waste site will have higher levels of concern and will be more skeptical of attempts to communicate levels of risk.

Older residents tend to have lower levels of concern about risks; conversely, young adults tend to be more sensitive to risks, especially new ones. There are several reasons for this general association with age and lower levels of concern. Older residents living near a site have likely been exposed to the risk for a long time without experiencing any significant consequences; they may consider it to be benign. Also, some older individuals may feel that they have less time left in which to suffer the consequences of long-term exposure.

People with families, especially those with young children, tend to have higher levels of concern. People with children may have higher levels of concern because they feel that they have "more to lose." Thus, many parents with young children will likely be very concerned about a Superfund site. Note that this very concerned group, because of family responsibilities and child care arrangements, is unlikely to attend community meetings or participate in other activities where risk information would be communicated. Thus, community relations personnel must be creative in finding ways to communicate to this very concerned group.

Occupation, income, ethnic background, and level of education have generally not been found to have an appreciable effect on levels of concern.

### 5.7 Reaction to Low-Level Risks.

In planning risk communication, it is important to understand how people interpret and respond to information about risks, especially risks with low probabilities but serious consequences. Virtually everyone--citizens, the news media, community relation officers, and even many technical experts--have difficulty with interpreting and responding appropriately to risks with low probabilities. Low probabilities are those with annual odds on the order of 1 in 100 or less. It is quite common for the serious risks associated with a Superfund site to be this low or lower so the communication problem will be quite difficult. In this section we describe the likely responses to communication about low probability risks.

When receiving new information about a low probability risk most people make one of two judgments. Some judge the risk to be a serious threat to , them, their families, or their property and so they have a high level of concern. Others decide that the chances of the risk are so remote that they dismiss the risk and act as if the probability of the hazard is zero.

It is often difficult to find grades of concern between these extremes for low probability risks; either people are very concerned or they are not concerned at all. Thus, people often do not make distinctions between low level risks, especially when risk levels are presented in terms of powers of ten such as  $10^{-5}$ . Although a risk of  $10^{-5}$  is 1000 times more likely than a risk of  $10^{-8}$  and although the level of concern should be about 1000 times greater, most people will make very little distinction between such risks. Either they will be very concerned or they will dismiss the risk as too unlikely to worry about.

The disparity in the two types of responses to information about low

probability risks has obvious implication for community conflict about a Superfund site. One group of citizens will be very concerned and so will be motivated to attend public hearings, write letters to the newspaper, circulate petitions, file lawsuits, etc. Another group of citizens will be unconcerned about the risk of the site but will become quite concerned about the activities of the other group. They will see the other group as needlessly "stirring up trouble" which, in their view, will result in unwarranted publicity and decreases in property values. For example, at a Superfund site in California, a concerned group of citizens formed an organization named "HELP" ("Homeowners to Eliminate Landfill Problems"). This group was in turn opposed by another group of homeowners who thought that HELP would only succeed in reducing property values. To reduce community conflict about a site, the community relations officer must be alert for possibilities to help each group understand the other group's concerns using techniques for conflict resolution such as those presented in the Appendix.

The community relations officer should also be aware that in some sense the response of neither group is appropriate. We make that statement cautiously because citizens are of course free to have whatever level of concern they believe appropriate. However, it is often the case that the responses of those in the very concerned group are inconsistent with their responses to other risks with similar probabilities and consequences. For example, use of certain household and garden chemicals or activities such as smoking may expose them to risks as large or larger than the risks posed by the Superfund site yet they have little or no concern for those other risks. It has been shown that experts do no better in their personal lives dealing with low level risks than the general public, so no individual or group is immune to the problem of over or under reacting to low level risks. Some of

our suggestions presented in Section 5.10 for communicating risk levels involve comparing the risk of the superfund site to comparable risks which are more familiar.

Just as some people are overly concerned, there are others who are completely unconcerned but sometimes ought to be more concerned. People who are unconcerned will be less motivated to heed warnings and to take precautionary actions that may be temporarily necessary for those living near a Superfund site. For example, an unconcerned resident might ignore a warning sign and trespass on a Superfund site because of good hunting or might not follow precautions about contaminated drinking water.

Given this information about the tendency for people either to be over- or under-concerned, the role of the community relations officer is to provide the best and most appropriate information so that people can make their own decisions. However, it will be most helpful if the credible source and the news media are provided with suggested actions (e.g., treatment of drinking water, avoidance of the site) that are appropriate for the level of the risk. But in the end, the community relations officer must be prepared for the fact that some people will be concerned that the actions are not enough and others will believe that they are too much.

It is also important for the community relations officer to understand that when thinking about risk and unfortunate events, people often make attributions about responsibility, attributions that are sometimes unwarranted. Blame for bad outcomes is usually attributed to something specific even if there is no evidence to justify such blame. This tendency to blame something in particular is especially true if there is already a community "bad guy." For example, the Superfund site or the former 'operator of the site may be labelled as this bad guy so that the blame for many random

events actually unassociated with the site will be attributed to the site. Thus, the cause of an otherwise unexplained cancer death of a resident living near the site or of a former worker at the site will almost surely be attributed to the site. Adverse pregnancy outcomes, the real cause of which is often difficult to determine, will also be attributed to the site.

An interesting example of false blame is provided by reactions at a Superfund site in California. An epidemiological survey by the state health department found an increased reporting of toothaches from residents living near the site. Even though there is no known biological mechanism by which anything at the site could cause toothaches, residents had a heightened awareness of any adverse event and were quick to attribute it to the neighborhood bad guy--the Superfund site.

When expressing levels of risk, complicated mathematical expressions (such as  $10^{-5}$ ) should be avoided. The community relations officer should also avoid the temptation to express the probability level in many different but equivalent ways. For example, a risk could be phrased in terms of how many people would be harmed per 10,000 people exposed (say, 2 in 10,000) or in terms of how many would not be harmed per 10,000 people exposed (9,998 in 10,000). Doing so may seem more complete than presenting only one expression, but so much information at the same time leads to confusions that can be fatal to a risk communication enterprise. There have been cases of such information being misconstrued and reported erroneously.

In summary, many problems may arise because people have difficulty in understanding low probability risks. Community relations personnel must try to provide information about risks in a manner that will not increase community conflict. An effective way to accomplish this is to compare the low probability risk to other familiar example risks. Precisely how to do this is described in Section 5.10.

## 5.8 Characteristics of the Risk.

There are a number of characteristics about a risk or hazard other than its probability or the seriousness of its consequences that influence response to the risk. In order to anticipate risk communication problems it is important for community relations personnel to identify the relevant risk characteristics associated with a particular Superfund site. It is usually not possible to change these characteristics, but just as knowledge of community characteristics is important in predicting response to risk information, so too is knowledge of the risk's characteristics. This section describes a few of the important characteristics of risks which help determine the level of concern.

The general effect of risk characteristics is to raise or lower the level of concern relative to comparable risks. Risks which tend to generate relatively lower levels of community concern are familiar, well-known to science, and undramatic. Conversely risks which tend to generate relatively high levels of community concern are unfamiliar, not well-understood by science, dramatic (in that many people might be killed or injured in a single event), and contain an element of dread.

Let's consider these characteristics in the context of typical Superfund sites. Familiarity is often a very important issue. Some sites are well known to community residents; residents will have had many experiences with the site such as just driving by without experiencing any effects. With such familiarity the level of concern will be much lower than for a site which poses a comparable risk but which has been covered up for many years and so the risk was unknown to the community. Similarly, if the risk is well-known or familiar to science, it will usually generate lower levels of concern. For example, if the risks at a site are due to chemical or toxic materials that

are commonly found and monitored in workplace settings and for which acceptable levels have previously been established, concern will be relatively lower than for toxics that are not well-understood and for which scientists are uncertain about acceptable levels. Whether or not the consequences of the risk are dramatic is also important. Some sites have risks where exposure now will result in a fatal illness many years hence while other sites have risks which are more immediate. Finally, there are some risks that people simply dread more than others. Radioactivity and cancer-inducing toxics are especially dreaded. So, even if the scientific estimates of the probability of harm were the same at two sites, the site with even small amounts of radioactivity or cancer-inducing toxics would produce a much higher level of concern in the community.

The task of risk communication therefore depends somewhat on the risk characteristics. If a site has characteristics which produce relatively high levels of concern, then the community relations officer will need to provide information that will help residents place the risk in its proper context. On the other hand, if a site has those characteristics which produce relatively low levels of concern, then the community relations officer must take special care to alert residents that a real risk does exist so that they will be motivated to take necessary precautionary actions.

#### 5.9 The Framing of Gains and Losses.

In preparing communications about risks associated with a Superfund site, it is important to determine whether the level of risk being communicated will be viewed by residents as an increase or decrease in the level of risk. That is, each resident will have some prior belief about the riskiness of the site; any risk communication will be responded to differently depending on whether the riskiness being communicated is higher or lower than that prior belief.

This is important because a perceived increase in risk will have between three and ten times the psychological impact on the level of concern because it is perceived as a loss than an equivalent reduction in risk which is perceived as a gain. Going from thinking you are safe to believing you are unsafe makes people a lot more unhappy than going from unsafe to safe makes people happy.

In the context of Superfund sites, for example, informing residents about an old waste site in their neighborhood about which they had no awareness will create a great deal of unhappiness because it is an increase in perceived risk and viewed as a loss. Conversely, telling people who have worried a lot about a known site for many years that the site is in fact very safe, even if they were to believe it, would not increase their happiness a great deal because it is a decrease in risk and viewed as a gain. This means that informing people about new risks and hazards must be done very carefully and that informing people about reductions in old risks is not likely to have much impact.

There are two important ways in which a risk level can be viewed as a change relative to the current perceived level: (a) the probability or likelihood of a hazard event may increase and/or (b) the consequences or severity of a risk may increase. Even slight increases in either or both will cause high levels of community concern while moderate or even large decreases in either or both will only slightly reduce levels of community concern.

#### 5.10 Use of Example Risks.

The previous sections have outlined the problems that must be addressed in any risk communication enterprise. Risk communication is broadly defined as both the physical reminders that are present at any Superfund site and the communication enterprise undertaken by the community relations personnel. It is important that both types of communication be monitored; too often only the

latter is given careful consideration. As noted in Section 5.6, community relations personnel must also be alert to characteristics of the community and to characteristics of the risk that will make risk communication more or less difficult. With that context of the difficulties of risk communication, this section describes a useful strategy for the accurate and understandable communication of levels of risk.

As noted in Section 5.8, some risks are better understood than others. Well-understood risks can be used to great advantage as a tool to help people understand new risks such as those posed by a Superfund site. This is most effectively done in a compare/contrast manner; for example, a low-level lung cancer risk posed by the site is presented with and compared to a high-level example risk, such as smoking. Explaining how much lower the site risk is than smoking helps the concerned citizens place the site risk in perspective, thus helping promote an appropriate level of concern. Familiar risks with comparable levels of risk can also be presented. For example, low-level example risks such as x-rays or saccharin may be presented in conjunction with analogous low-level site risks. Naturally, care must be taken that comparisons between risks are scientifically valid, and it is especially helpful if the example risks have many characteristics (see Section 5.8) in common with the site risk (such as the lung cancer example, above).

A particularly good procedure for using example risks is the risk ladder. Instead of a few example risks, the ladder contains many types and levels of risk, arranged on a risk scale. An example of a ladder that has been particularly useful for these situations is given in Figure 5.1. The risks on the ladder are generally well-understood risks, presented with their actual risk level. The site risk can be added to the ladder, in its proper place in comparison to the example risks, and the ladder can be presented to concerned citizens. This procedure is much more effective than presenting the

risk by itself because context has been established. Thus, citizens can view the risk in a more natural, real-world context.

Two very important guidelines must be followed when example risks and ladders are used. First, the example risks themselves must be well-understood risks that do not cause inappropriate levels of concern on the part of the public. Thus, risks that are considered unknown or dreadful (see 9.7) are inappropriate as example risks. It would be unwise, for example, to use nuclear war or AIDS as example risks. Better risks are those given on the risk ladder (Figure 5.1).

A second important guideline concerns the choice of ladders versus one or two example risks. It should be remembered that the ladder, while effective, takes time to read and understand, and would be cumbersome for the media, for example, to use effectively. It is better to present one or two appropriate example risks, explaining in detail the nature of the comparison and repeating the risk levels to make sure they have been understood. Otherwise, it is possible for a misunderstanding to arise, and the high-level contrast example risk (e.g., smoking) could be construed as analogous to the site risk, thus confusing and alarming citizens.

Example risks, then are an effective tool for communicating risks. A risk ladder of many risks is especially useful, but only for situations in which it would not be cumbersome. Finally, example risks must be chosen carefully, or risk perception will be further confused.

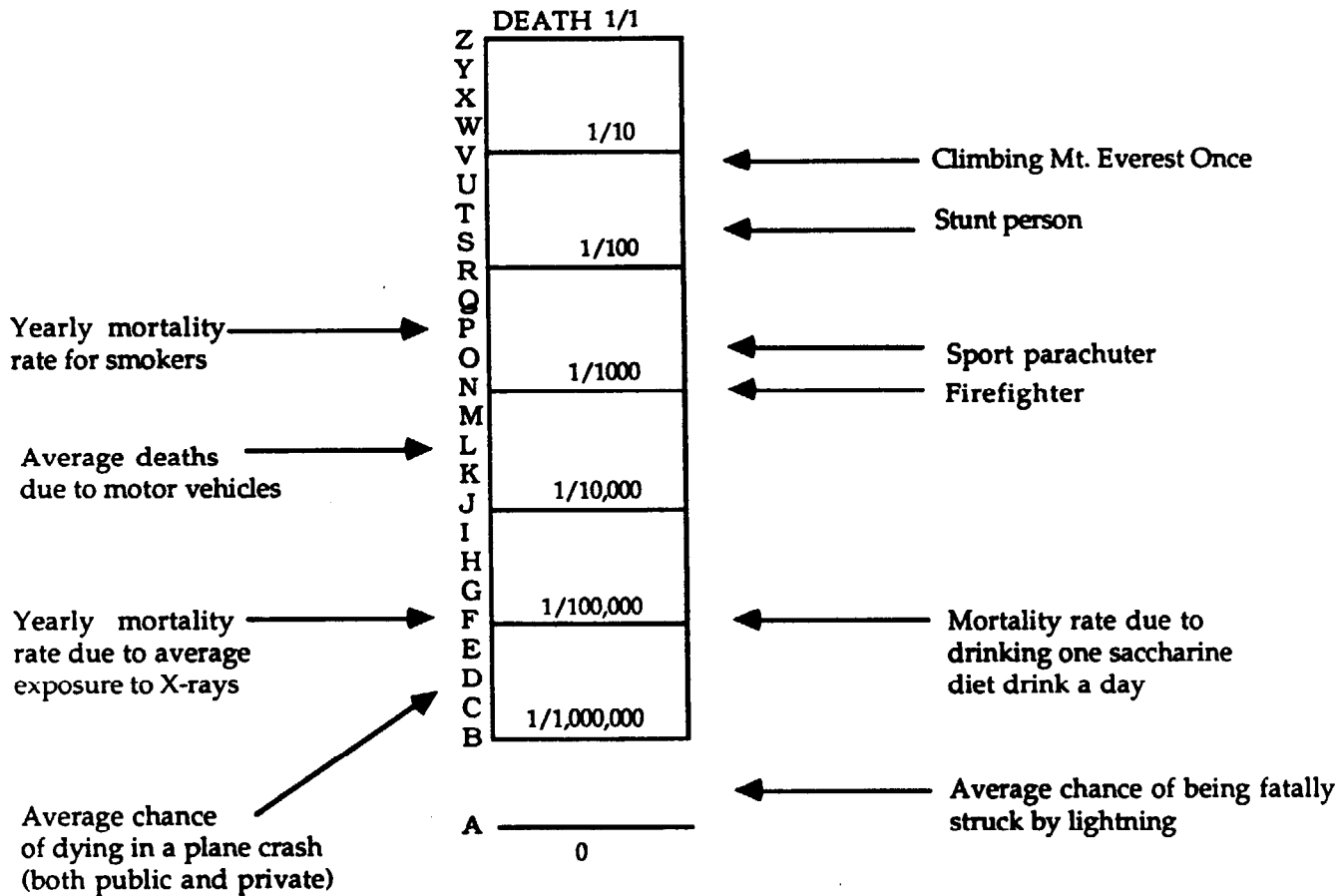
#### 5.11 Recommendations.

This section will refer to the guidelines already established in previous chapters. The purpose of these recommendations is to give some examples of risk communication situations, and to suggest effective ways of performing risk communication in those situations.

FIGURE 5.1

## ANNUAL CHANCE OF DEATH

(Unless otherwise specified, risk is for one year of exposure)



1. The neutral, well-respected group of risk experts (scientists, usually) that is chosen to assess the site should report to a credible level of government. Sometimes, however, trust has deteriorated, and no government body in the area is considered credible. In this case, a citizen committee should be formed. The risk experts then report to these respected citizens, and the citizens communicate the risk to the community at large.
2. Certain communities or neighborhoods, especially those with young families, will be more likely to have very high levels of concern. These areas should be targeted for careful communications, remembering that these families are the least able to participate in traditional public hearings.
3. Information about levels of risk should be expressed in concrete terms, using example risks or the risk ladder. Also, physical reminders should be monitored so that they communicate a level of risk consistent with the actual level of risk.
4. The news media easily can inadvertantly become a catalyst for inappropriately high levels of concern. To prevent this, complete and consistent information should be provided to the news media, starting as early as possible before the news media's beliefs have been formed and reported. If the news media nevertheless begins to escalate concern on the part of citizens, the risk communication officials must increase the effort to counteract misleading information. For example, if non-experts are interviewed, then experts should become available to the news media, providing accurate information and addressing the non-experts' information. Example risks should also be provided, although too many example risks (as in a risk ladder) could

- be counter productive given the brief coverage typically provided by the news media. In all risk communication enterprises, probability
5. phrases should be utilized with caution. Low probabilities are especially problematic; probabilities at or below one in one hundred are poorly understood. Expressing long-range probabilities (the risk over a period of many years, for example) is often helpful because it brings the probability level to a better-understood range. Also, pairing probabilistic information with example risks and risk ladders helps citizens put the numbers in context.
  6. Complicated mathematical expressions (such as  $10^{-5}$ ) should be avoided, as should too many permutations of numeric information.

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## A P P E N D I X

### **Science, Values, and Human Judgment**

Kenneth R. Hammond and Leonard Adelman

## Science, Values, and Human Judgment

Integration of facts and values requires the scientific study of human judgment.

Kenneth R. Hammond and Leonard Adelman

Scientists and policy-makers are uncertain how scientific facts are to be integrated with social values. For their part, scientists are uncertain whether their contributions should be restricted to presenting the facts, thereby leaving the policy judgment entirely to the political decision-makers, or whether they should also advise politicians which

course the scientist believes to be best. And politicians, for their part are uncertain how much scientific information they are supposed to absorb, and how much dependence they should place on scientists for guidance in reaching a judgment about policy (1). As a result, "the scientific community continues its seemingly endless debate about the role of

science and scientists in the body politic" (2).

One principal reason for the "endless debate" is that scientific progress has increasingly come to be judged in the context of human values. These judgments find their ultimate expression in the forming of public policy because it is during that process that the products of science and technology are integrated, or aligned, with human values: it is during that process that scientific and technological answers to questions of what can be done are judged in the content of what ought to be done.

The key element, therefore, in the process of integrating social values and scientific facts is human judgment—a cognitive activity not directly observable and generally assumed to be recoverable

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only by (fallible) introspection and "self-report." These characteristics, among others, have led to the general belief that human judgment is beyond scientific analysis and therefore little has been learned about the cognitive activity that produces crucial decisions. The integration of social values and scientific information in the effort to form public policy remains largely a mystery.

The fact that an essential element in the policy formation process remains a mystery has serious consequences, one of which is a search for safeguards. Means must be found to avoid both poor judgments and self-serving judgments. TWO general methods have been recommended by scientists for these purposes: (i) the adversary method, in which scientists with differing judgments are pitted against one another in front of a judge or jury, or both, and (ii) the search for and use of scientists who have somehow gained a reputation for wisdom in the exercise of their judgment. Neither of these methods provide enlightenment with regard to the judgment process that produces the ultimate decision. Consequently, we reject both methods because they are "ascientific": they leave the body politic at the mercy of a cognitive activity which remains as much a mystery as ever.

We contend that policy judgments can be brought under scientific study and, as a result a process that is now poorly understood can be examined, understood, assisted, and thereby improved. To support this contention we describe a scientific framework for integrating (i) scientific information (the province of scientists) and (ii) social value judgments (the province of the electorate and their representatives) in a manner that is scientifically, socially, and ethically defensible, and offer an example of its use. First, however, we briefly consider two contrasting viewpoints concerning the role of science and scientists in the body politic.

### Contrasting Viewpoints of the Role of the scientist

There are two main viewpoints: one is that scientists should merely present unbiased information, while the other is that scientists should provide advice with regard to the implications of scientific information. The first view can be illustrated by the comments of Phillip Handler, president of the National Academy of Sciences (NAS), in an interview with Otten, of the *Wall Street Journal*.

Often (3) writes; "Once the scientific community has presented the facts, however, it must leave final decisions to the policy-makers and the public. Mr. Handler asserts. "Science can contribute much to enhancing agricultural production, but American policy with respect to food aid is not intrinsically a scientific question." Similarly, science can study whether energy independence is technically feasible or whether Soviet underground nuclear tests can be detected, but [Handler] insists, [scientists] must then let regular policy-makers decide whether to try for energy independence or just what arms control proposals to put to the Russians." Often concluded that "Both science and government seem well served by this reasonable man."

Handler's viewpoint as represented in the above quotation is exactly in accord with the two Executive Orders (1918, 1956) concerning the role of the National Research Council. These documents indicate that scientists are to render information to those who are entitled to receive it, but they do not imply that scientists should offer their judgment as to what public policy should follow from their studies.

In practice it may be impossible not to offer such judgments. With the ever-increasing reliance of society on science and technology it is difficult to imagine how modern scientific information could be conveyed to nonscientists without providing such judgments. In a recent editorial in *Science*, Boulding (4) argued that if policy judgments were not offered by scientists, they would be demanded by politicians.

Every decision involves the selection among an agenda of alternative images of the future, a selection that is guided by some system of values. The values are traditionally supposed to be the cherished preserve of the political decision-maker, but the agenda, which involves fact or at least a projection into the future of what are presumably factual systems, should be very much in the domain of science. . . . [But] if the decision-maker simply does not know what the results of alternative actions will be, it is difficult to evaluate unknown results. *The decision-maker wants to know what are the choices from which he must choose* [italics ours].

Toulmin (5, pp. 102-103) goes further than Boulding. Whereas Boulding notes that politicians may demand policy judgments from scientists, Toulmin argues that it may be part of the scientists' responsibility to offer policy judgments before such judgments are requested by political decision-makers. Thus, "In the early days, the picture was always of the politician as the man who *first* formulated for himself questions about the po-

litical options, about the choices he had to make: on this view, he *subsequently* turned to people called "technical advisors and asked them how to do this or that, how much each option would cost, and so on. A 101 of people still see the relationship between the scientist or technologist and the politicians on this model. . . ." But, Toulmin observes, " . . . even during [World War II] scientists were being transformed into people who could very often see a fresh range of policy options *before* the politicians could." Significantly, Toulmin notes that "To some extent, the institutional relationships between politics and science have not yet caught up with this change."

Thus, Toulmin points out that the decision-maker not only wants to know "the choices from which he must choose," as Boulding put it, but he also wants to know which choice the scientist thinks he should choose. Senator Muskie's call for a "one-armed scientist" (one who would not qualify his advice with "on the other hand") exemplifies the politician's demand for an unequivocal answer to the question of what ought to be done as well as to that of what can be done.

This situation has not escaped the attention of students of the role of scientists in the formation of public policy. The presence of, the demand for and the exercise of value judgments has led to a sharp focus on the values and thus on the motives of the scientists who participate in the preparation of NAS reports that affect public policy.

### The Focus on Scientists and Their Motives

In his book *The Brain Bank of America* (6, p. 54) Boffey attributes self-serving motives to scientist who provide information and advice to the government within the framework of NAS committees, and thus questions their objectivity and honesty. For example:

The Academy claims that the most distinctive feature of its committees is that they are independent of any pressure of special interests. . . . But the Academy's record in recent years suggests that its protestations of Supreme Court impartiality should not be taken at face value. In actual practice many of the Academy's reports have been influenced by powerful interests that have a stake in the questions under investigation.

Boffey admits, however, that "We found no cases of direct, personal conflict of interests at the Academy—no cases, for example, where a committee member profited financially as a direct

result of the advice he rendered" (6, p. 54). The charge that "many of the Academy's reports have been influenced by powerful interests" is directed toward the broader social and political motives which he claims influence scientists' judgments.

The NAS has already accepted the principle that the motives of scientists must be examined. Boffey (6, p. 87) notes with approval that the NAS demands a "bias statement" from the scientists who provide information to the government, a report that is intended to reveal one's true interests, as may be inferred from a list of "all jobs, consultancies, and directorships held for the past 10 years, all current financial interests whose market value exceeds \$10,000, or 10 percent of the individuals holdings: all sources of research support for the past five years, and any other information." such as public stands on an issue which 'might appear to other re-sortable individuals as compromising of your independence of judgment. " Thus the NAS has already fallen victim to the ethic of the lawyer (and the journalist). Trust no one, is the rule, unless they can offer this negative proof: I am not now, nor have I ever been, under the control of any incentive to lie, cheat, or otherwise compromise my judgment. Whereas this approach may begin with a request for a "self-report" on sources of bias, it seldom ends there, as scientists know all too well. Investigation is undertaken by others, and by other means, precisely because the focus has been successfully turned away from methods to persons and their motives.

The results of the focus on persons and their motives can be seen in Poisby's review (7) of Boffey's book. Poisby indicates what the results might have been had he taken a similar approach in his review by raising suspicions about Boffey's impartiality and thus his motives. That is, by using "Boffey's own primary method of demonstration: a glance at somebody's background gives a 'motive' for selected characteristics of his performance." Poisby finds that "Boffey's employer for the writing of this book was Ralph Nader (identified as "consumer champion Ralph Nader" on p. 186), who of late has gotten rather heavily into the business of sponsoring exposes of establishment-type establishments. . . . Under these circumstances of employment, could Boffey have done other than to produce an attack, no matter how flimsily founded, on the Academy?" (7, P. 666).

Poisby's review shows the customary

result of such mutual destruction. Boffey's approach, he concludes, "is only good for so much mileage. . . . Arbitrarily imposing the symmetrical assumption . . . that Boffey and the Academy are both fatally incapacitated by conflict of interest has the effect of condemning both the Academy and the book out of hand" (7, p. 666). In short, because neither the critic nor those criticized can be trusted, the reader, the consumer, and the public remain buried in doubt as to where the truth lies. Thus, Poisby acknowledges that, "After reading *The Brain Bank of America* I do not know what to think about the Academy as an organization for evaluating the state of scientific knowledge" (7, p. 666). In all likelihood, Poisby is not the only reader of Boffey's book who no longer knows what to think about the Academy.

It is precisely because scientists have learned that it is not only fruitless, but harmful, to focus on persons and their motives that they have learned to ignore them in their work as scientists. When scientists look for the truth and the truth appears to be in doubt, neither scientific work nor the scientific ethic requires the investigation of the characteristics of the person working on the problem: instead, they require the analysis of the method by which the results are produced. Unfortunately, in the confusion of the "endless debate" there has been a tendency to forget the scientific procedure and its associated ethics. The focus on persons and their motives has led not only to the filing of bias statements but to the advocacy of the adversary method for the settlement of disputes about the truth--a method which is ascientific not only in its procedure, but in its greater commitment to victory rather than to truth.

### Scientists as Adversaries

The concept of a "science court" reached Congress several years ago when Kantrowitz (8) urged that members of Congress "appoint a science advocate for (each) side of the story. . . ." He further suggested that a procedure be worked out which would be "modeled on the judicial procedure for proceeding in the presence of scientific controversy." The final judgment would be exercised by a group of scientific judges who would cross-examine each other and challenge each other's position. Kantrowitz's argument is currently being given serious consideration by members of the scientific community. *Physics Today* (published by the American Institute of

Physics) recently indicated that a science court was worth trying, as did H. Guyford Stever, director of the National Science Foundation (9).

Members of the scientific community are not unanimous, however, in their appraisal of the value of the adversary system, as the following interchange between Platt, Dror, and Waddington in a Ciba symposium indicates (10, p. 210):

PLATT: In the U.S. . . . we are beginning to have something called "adversary science," where scientists speak on public issues, doing their best like lawyers for a particular side, and then in a later case perhaps doing their best for the opposite side. The hope is that in this kind of open confrontation as in a court of law one comes closer to the truth than by having just 1 accidents of committee structure or unanswered polemics decide the matter.

WADDINGTON: I would strongly oppose that way of advancing science.

PLATT: But somebody should make the total case for a nuclear plant, and somebody should make the total case against the plant for environmental reasons, so that we can see all of both sides before we decide.

DROR: Why shouldn't the two sides make two balanced presentations for and against? Why total . . . ?

PLATT: Do you know a better system?

DROR: Yes, reliance on professional judges in courts and careful policy analysis on television for the public.

PLATT: Who judges the judges?

DROR: Who judges the juries?

WADDINGTON: That is a piece of politics, not a piece of learning. Learning is not advanced by legal procedures.

The above interchange not only indicates a divergence in viewpoint with regard to a science court and illustrates the morass (Who judges the judges? Who judges the juries?) into which scientists can be drawn because of the focus on persons but it also points to the unproductiveness of the effort. Even if the concept of a science court were to be accepted by scientists and even if scientists could be persuaded to make the "total case for (say) a nuclear plant" (10, p. 201), the adversary procedure would indicate only who had been judged to be the winner in the arena of competing scientific facts and Scientific judgments, integration of scientific judgments with social values would remain buried in the minds of the judges and the juries (and their judges): the "endless debate" would not be terminated.

It remains to be seen whether a science court with its judges and juries and its ascientific adversary proceedings in which one scientist is pitted against another will be accepted by scientists. In any event, scientists not advocating the adversary method recommend a different ascientific method the person-oriented approach.

## Scientists' Advocacy of the Person-Oriented Approach

When scientists have addressed themselves to the function of human judgment in policy formation they have treated the unexamined intuitive abilities of persons as though they were somehow superior to the scientific method. For example, in its report on technology assessment to the House Committee on Science and Astronautics, the Committee on Public Engineering Policy (COPEP) of the National Academy of Engineering observed (11, p. 17) that "applying only cause-effect [i.e., scientific] methods to technology-initiated studies produces a mass of data but few broad conclusions." Apparently assuming that it had no other recourse the committee called for "... contributions of talented individuals or groups who can intuitively perform analysis and evaluations . . ." an approach which "demands an integrated combination of information and value judgments that cannot always be formulated explicitly."

Not only does the COPEP report illustrate the advocacy of a person-oriented approach to the combination of "information and value judgments" that appeals to the mysterious as a substitute for the scientific method, it provides a clear case of the failure to recognize that it is precisely such person-oriented "combinations of information and value judgments that cannot always be formulated explicitly" that are defenseless against charges of self-serving bias.

Skolnikoff and Brooks (12) were critical of the NAS study of science and public policy-making because it suggested that persons who provide science advice should have personal qualities of "intelligence wisdom judgment humanity and perspective" on the ground that "These qualities are so obviously desirable for anybody in a high position that they are hardly helpful criteria." Yet they are as willing as COPEP or the NAS committee to let the process of combining facts and values remain subject to the unexamined vagaries of human judgment. For example (12, p. 38):

Judgment on both technical and nontechnical issues and on their interaction is thus required [on policy issues]: a logically reasoned single answer is not possible. Judgment is necessarily affected by biases policy preferences, ignorance differing estimates of the nontechnical factors and other vagaries. There is nothing wrong with this: it is unavoidable.

But there is something wrong with this, and this situation is avoidable. What is wrong is that both solutions indicated above focus on persons rather

than on method, and both confuse scientific and evaluative judgments. That is bad practice: it is bad for scientists, bad for leaders in government, and bad for the public that both are trying to serve. It is bad because it condones and encourages confusion of thought and function, substitutes an appeal to the unknown in place of the knowable, and makes scientists easy targets for charges of self-serving bias. The argument advanced by Skolnikoff and Brooks merely puts a brave face on a bad situation, for they imply that because scientific and evaluative judgments cannot be separated there is nothing wrong with confusing them. That argument suggests that if such judgments could be separated, it would be wrong to confuse them. We argue that, from the point of view of science, it is not impossible in principle or in practice to achieve such a separation (13).

A scientific approach toward the role of judgment would be quite different from the person-oriented approach that is embedded in the adversary system. A scientific approach would emphasize that judgment is a human cognitive activity and is therefore subject to scientific analysis, as are all natural phenomena. The premises of a scientific approach to the relation of science to public policy are: (i) human judgment is a critical part of the policy-making process; (ii) it is a part of the process that remains poorly understood; and (iii) it might well be improved through scientific study. Rather than searching for persons who possess mysterious talents, or indicating that the present situation is unavoidable, the scientific approach to this problem would be similar to the scientific approach to all problems: carry out theoretical and empirical analyses of the process in a manner that is subject to criticism and that provides cumulative knowledge.

The remainder of this article (i) provides an example that illustrates the social costs of employing the adversary system and the person-oriented approach and (ii) outlines a scientific framework for integrating scientific information and social values in the formation of public policy (14).

### An Example of Contrasting Approaches

In 1974, the Denver Police Department (DPD), as well as other police departments throughout the country, decided to change its handgun ammunition. The principal reason offered by the police was that the conventional round-

nosed bullet provided insufficient "stopping effectiveness" (that is, the ability to incapacitate and thus to prevent the person shot from firing back at a police officer or others). The DPD chief recommended (as did other police chiefs) the conventional bullet be replaced by a hollow-point bullet. Such bullets it was contended, flattened on impact, thus decreasing penetration, increasing stopping effectiveness, and decreasing ricochet potential.

The suggested change was challenged by the American Civil Liberties Union, minority groups, and others. Opponents of the change claimed that the new bullets were nothing more than outlawed "dum-dum" bullets, that they created far more injury than the round-nosed bullet, and should, therefore, be barred from use. As is customary judgments on this matter were formed privately and then defended publicly with enthusiasm and tenacity, and the usual public hearings were held. Both sides turned to ballistics experts for scientific information and support.

### Adversary, Person-Oriented Approach

From the beginning both sides focused on the question of which bullet was best for the community. As a result of focusing on bullets and their technical ballistics characteristics, legislators and city councilmen never described the social policy that should control the use of force and injury in enforcing the law: they never specified the relative importance of the societal characteristics of bullets (injury stopping effectiveness or ricochet). Instead, the ballistics experts assumed that function. When the legislators requested their judgment as to which bullet was "best," the ballistics experts implicitly indicated the social policy that should be employed. That is in recommending the use of a specific bullet, they not only implicitly recommended specific degrees of injury, stopping effectiveness, and ricochet but also recommended a social policy regarding the relative importance of these factors. In short, the legislators, function was usurped by the ballistics experts who thus became incompetent and unauthorized legislators-incompetent because of their lack of information about the social and political context in which a choice would be made: unauthorized because they assumed a function for which they had not been elected.

In parallel fashion, the ballistics experts turned their scientific-technical function over to those who should have

formed social policy-the legislators. When the experts presented scientific information to policy-makers about various bullets, they found themselves disputing ballistics data with legislators who preferred a different type of bullet. Thus, the legislators, none of whom were ballistics experts in their turn served as incompetent ballistics experts in the hearings.

When legislators and scientists accept the adversary system with its concomitant person-oriented approach as the primary means for integrating science and social values, they may expect to find a reversal of roles, and when scientists accept the person-oriented approach they may expect to be confronted by challenges to their objectivity (15). The outcome is well represented by the comment of one legislator who said to an opponent (16): "You have your expert and we have ours. . . ."

### A Scientific Approach

We now consider, by way of an example, a scientific method for integrating scientific information and social values that is scientifically, socially, and ethically defensible. This method was employed in solving the dispute about handgun ammunition for the police as described above. A broad outline of the method is presented (17).

The general framework of the method as it was applied to the above problem is shown in Fig. 1. Basic to any policy involving scientific information are objectively measurable variables (Fig. 1, left). Scientific judgments regarding the potential effects of technological alternative are also required (Fig. 1, middle). Finally, social value judgments by policy-makers or community representatives are necessary (Fig. 1, right). The overall acceptability of an alternative is determined by how closely its potential effects satisfy the social values of the community.

Application of this framework to the bullet dispute involved three phases: (i) externalization of social value judgments; (ii) externalization of scientific judgments; and (iii) integration of social values and scientific judgments. Each phase is discussed in turn.

### Phase 1: Externalizing Social Value Judgments

The participants in phase included the mayor and city council other elected officials representatives of the DPD

(including the chief), and official representatives of community organizations, including minority groups and members of the general public. Each person was asked 10 make judgments concerning the

relative desirability of hypothetical bullets, described in terms of their (i) stopping effectiveness, (ii) severity of injury, and (iii) threat to bystanders. These value judgments were made at the console

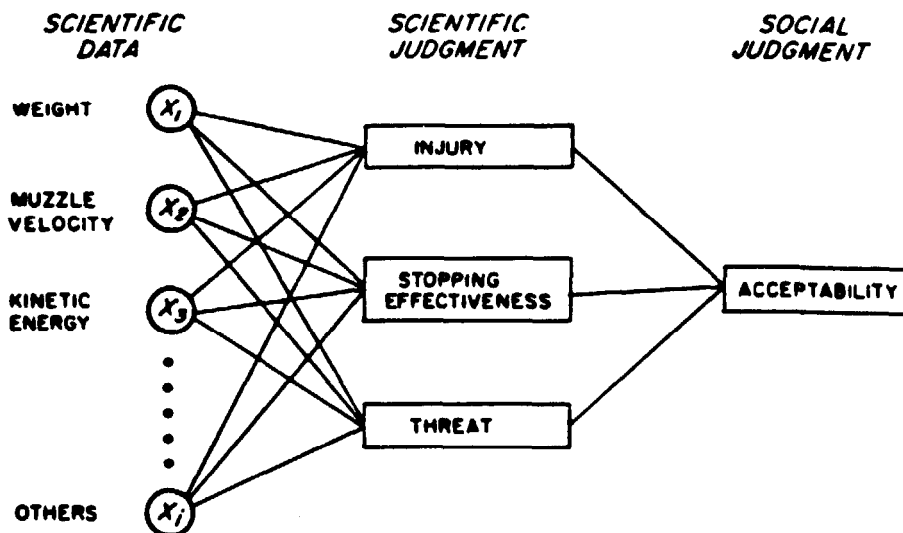
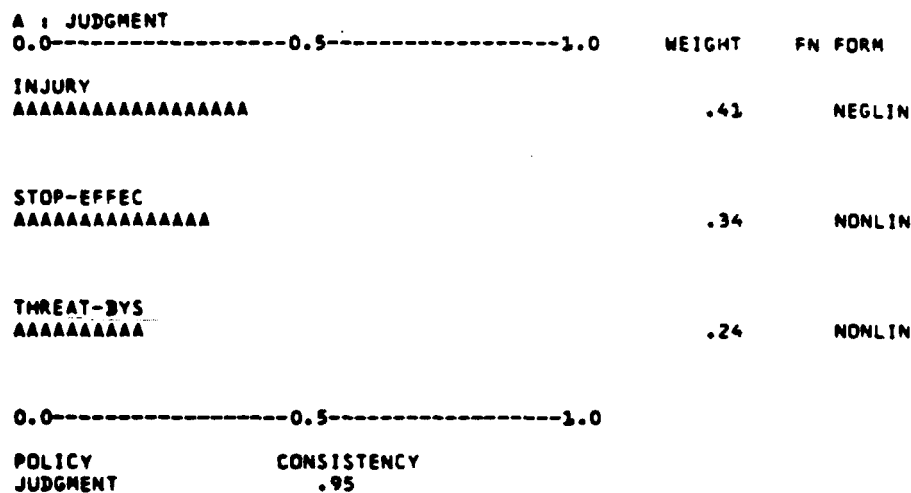


Fig. 1. A pictorial representation of a framework that combines scientific facts with social values.

### RELATIVE WEIGHT PROFILE



### FUNCTION FORM PROFILE

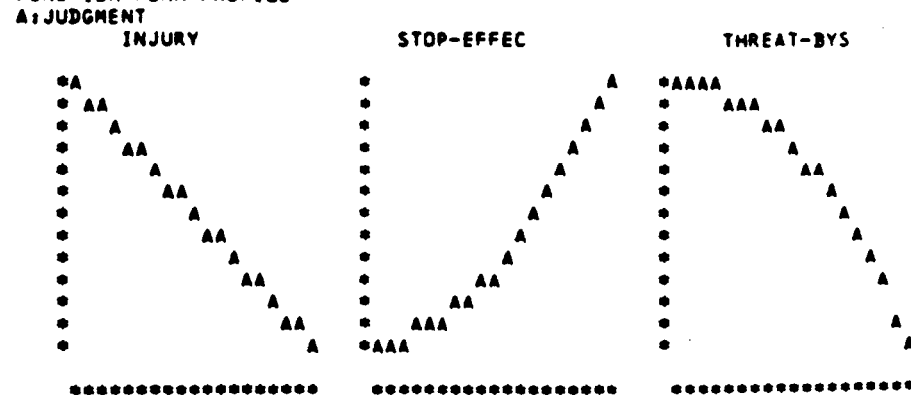


Fig. 2. A reproduction of a participant's interactive computer display of relative weights and functional relations, FN, function: NEGLIN, negative linear, NONLIN, nonlinear.

of an interactive computer terminal. After their judgments were made the participants were immediately shown the relative importance they gave to each of these three functional characteristics of bullets. That is, a statistical analysis was carried out on the data and the results were then displayed at the terminal for the participant to observe (18). In addition, each participant was shown the form of the relation (linear curvilinear) between his or her judgment and each of the three characteristics mentioned above. In this way, each participant saw the relative importance he or she attached to stopping effectiveness, injury, and threat to bystanders, as well as the optimal point for each (a typical display is shown in Fig. 2).

After viewing the display, the participants were asked if the results reflected their considered judgment. The data cor-

rected when necessary, were then stored, and a cluster analysis was carried out in order to discover whether different groups held different judgment policies. Widely differing policies with regard to the relative importance of each characteristic were found, although the functional relations between bullet characteristics and judgments were all found to be approximately linear in form.

The above procedure presides objective, visible data not otherwise available. The same procedure was used to externalize the required scientific judgments.

## Phase 2: Externalizing Scientific Judgments

A panel was assembled that included one firearms expert, one ballistics expert and three medical experts in wound

ballistics. The judgments of these experts provided scientific information regarding the stopping effectiveness, severity of injury, and threat to bystanders of 80 bullets. The data for these bullets were obtained from the National Bureau of Standards. Each dimension (stopping effectiveness, injury and threat to bystanders) was judged separately for each of the 80 bullets; agreement among the experts was found to be quite high (19). Only the results for stopping effectiveness and injury are summarized here, as these were the central factors in the controversy.

Three factors were found to be important in judgments of stopping effectiveness: (i) The maximum diameter of the temporary wound cavity; (ii) the amount of kinetic energy lost by the bullet in the target; anti (iii) the muzzle velocity of the bullet. The close but not perfect relation between stopping effectiveness and injury (shown in Fig. 3) is reflected in the fact that independent judgments of potential injury were positively related to the amount of kinetic energy lost maximum diameter of the temporary cavity and degree of penetration.

The data in Fig. 3 are important because they suggest that contrary to previous, unexamined assumption there is not a perfect relation between stopping effectiveness and injury: increasing one does not necessarily increase the other. These data illustrate the value of scientific information by indicating the possibility of finding a bullet that increases stopping effectiveness without increasing injury (20).

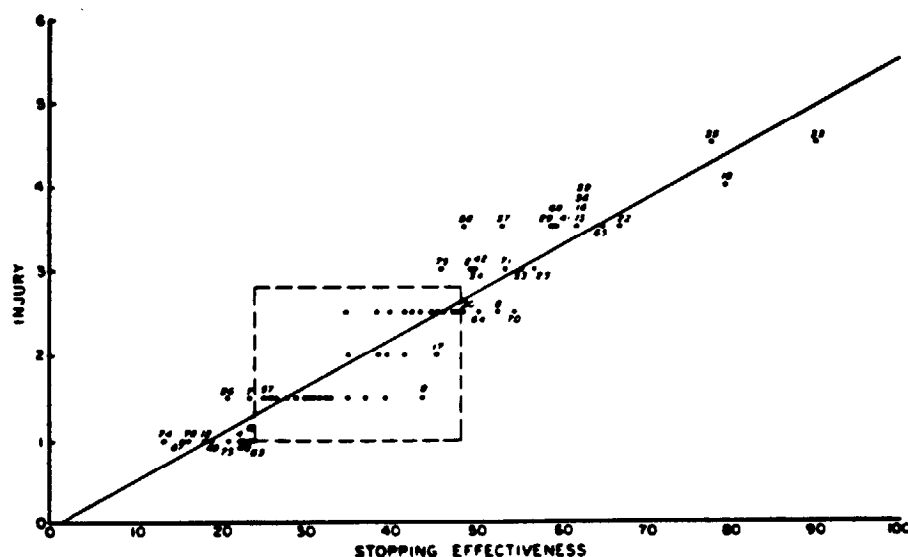


Fig. 3. the average rating of stopping effectiveness and injury are plotted above. Each point on the graph represents a bullet. The diagonal line determined by linear regression analysis, indicates the average value of injury for bullets with a specific level of stopping effectiveness. Bullets above the line produce more injury than the average bullet with the same stopping effectiveness bullets below the line produce less injury.

## Phase 3: Integrating Social Values and Scientific Information

Social value judgments and scientific judgments were combined by means of the equation in Fig. 4, where the separation and combination of the judgments of policy-makers and scientist-technologists may be seen. We used the following algebraic form of this equation

$$Y_j = W_1X_{1j} + W_2X_{2j} + W_3X_{3j}$$

where  $Y_j$  is the overall acceptability of a bullet;  $W_j$ ,  $j = 1, 2, 3$ , indicates the weight, or relative importance policy-makers placed on stopping effectiveness, injury, and threat to bystanders; and  $X_j$ ,  $j = 1, 2, 3$  are the experts judgments regarding stopping effectiveness, injury and threat to bystanders.

Because phase I resulted in a variety of different weights on stopping effectiveness, injury, and threat to bystanders,

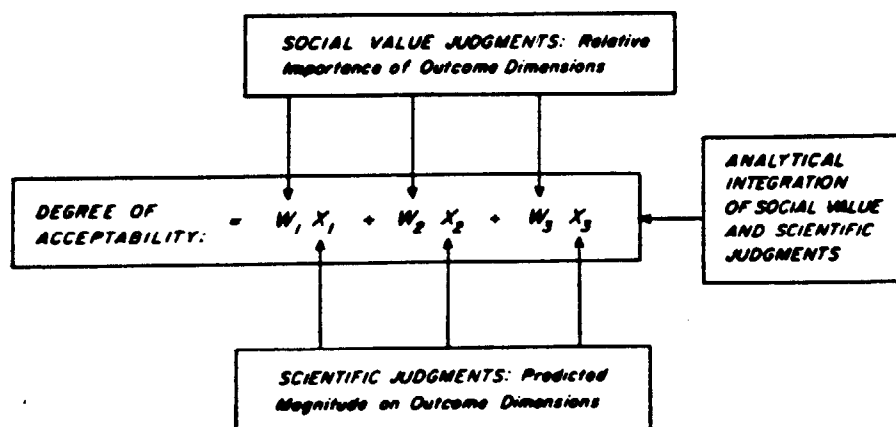


Fig. 4. A schematic representation of the analytical combination of scientific facts and social values.

the city council took all three factors into consideration by placing equal weight on each. As a result, when considering stopping effectiveness and severity of injury only, the appropriate bullet is one which lies farthest from the line of average relation in Fig. 3. This distance from the line being measured perpendicularly from the point to the line. Bullet 9 in Fig. 3 satisfies this criterion. It has greater stopping effectiveness and is less apt to cause injury (and less apt to threaten bystanders) than the standard bullet then in use by the DPD (bullet 57). In addition, bullet 9 (a hollow-point bullet) is less apt to cause injury than is bullet 17, the hollow-point bullet recommended by the DPD. Bullet 9 was accepted by the city council and all other parties concerned, and is now being used by the DPD (21).

Finally, three points should be mentioned with regard to the application of judgment analysis to the above problem,

1) Intense political and social conflict existed prior to our participation in the project. During the controversy a Denver police officer was killed by a hollow-point bullet: as a result, hundreds of policemen staged a march that ended in demands on both the police chief and the governor that the police be permitted to use hollow-point bullets. Members of the city council and others seemed convinced that the usual adversary methods had failed, and that they faced a dangerous impasse. The fact that the above procedures were used in these circumstances indicates that elected officials and special interest groups can accept a scientific approach to critical social problems, even when they have become immersed in sharp political dispute. Moreover, interviews with members of the city council and others not only indicated a high degree of satisfaction with the procedure but appreciation of its impersonal approach as well.

2) The procedures were applied to complex technical judgments. As far as we could determine at the time of the research no standard quantifiable definition of severity of injury (with regard to handgun ammunition) had ever been developed. Moreover, in developing such a definition, and in making their judgments, the ballistics experts considered 11 distinct characteristics of handgun ammunition.

3) The procedure is general in nature. Despite the apparent simplicity of the framework presented in Fig. 4, judgment analysis can be applied to a variety of complex problems involving value judgments and scientific judgments by differentiating the elements in Fig. 4 in a hierarchical fashion (22).

## Scientific Defensibility

The above method is scientifically defensible not because it is flawless (it isn't), but because it is readily subject to scientific criticism. It is vulnerable to such criticism (i) because its aim is to meet appropriate standards regarding replication, quantification and logic for the problem under study (an aim all scientific efforts share) and (ii) because the procedure for achieving that aim is public (as all scientific effort must be). The locus and degree of imperfection in method and procedure are thus available for public inspection and subsequent improvement. In short, the process provides the opportunity for cumulative knowledge, as scientific efforts should.

## Social Responsibility

The above method is socially responsible because it provides a public framework for (i) separating technical, scientific judgment from social value judgments and (ii) integrating them analytically, not judgmentally. The separation phase permits elected representatives to function exclusively as policy-makers, and scientists to function exclusively as scientists. Neither role is confused or exchanged because policy-makers are not forced to become amateur scientists, nor are scientists required to make judgments on public policy. The integrative phase provides an overt, rather than covert, process for combining facts and values. Because the social values in the community are identified before the decision is implemented, the decision process is not seen to be a mere defense of a predetermined choice: rather it can be evaluated in terms of its rational basis before the final choice is made.

## Ethical Standards

Ethical and scientific standards converge in the process of combining facts and values because both scientific ethics and public ethics require controls against bias. Scientific control against bias is illustrated by the use of the double-blind control in experiments: in the above procedure public control against bias is carried out by a similar blindness. That is, the method described above has the advantage of situating all parties (policy-makers, scientists, and the public) behind what Rawls (23, p. 136) calls "a veil of ignorance." It fits Rawls' requirement that the participants should not "know how the various alternatives [would] af-

fect their own particular case and they are obliged to evaluate principles solely on the basis of general considerations," in the approach described above, the technical experts were not aware of the relative importance the policy-makers placed on the three societal characteristics of bullets, nor were the policy-makers aware of the technical judgments made by the scientists-technologists in regard to specific bullets. In short by implementing Rawls' veil of ignorance, both scientific and ethical standards were met.

## Conclusion

Current efforts to integrate scientific information and social values in the forming of public policy are confused and defeated by the widespread use of ascientific methods--the adversary system and the person-oriented approach. The adversary system suffers from an ascientific commitment to victory rather than truth: the person-oriented approach suffers from an ascientific focus on persons and their motives rather than on the adequacy of methods. The reason for the widespread use of both lies in the failure to recognize that human judgment can be brought under scientific, rather than ad hominem, analysis. The argument advanced here is that a scientifically socially, and ethically defensible means for integrating science and human values can be achieved.

## References and Notes

1. See, for example, Public Law 92-484 which established the Office of Technology Assessment.
2. J. W. Curtin, *Science* 190, 839 (1975).
3. A. L. Otten, *Wall Street Journal*, 3 April 1975, p. 12.
4. K. E. Boulding, *Science* 190, 423 (1975).
5. S. E. Toulmin, in *Civilization and Science: In Conflict or Collaboration?*, Ciba Foundation Symposium 1 (Elsevier, Amsterdam, 1972).
6. P. Bodley, *The Brain Bank of America* (McGraw-Hill, New York, 1975).
7. N. W. Polshy, *Science* 190, 665 (1975).
8. Hearings before the House Committee on Rules and Administration (1971).
9. See the article by J. N. Wilford, *New York Times*, 19 February 1976, p. 3.
10. *The Future as an Academic Discipline*, Ciba Foundation Symposium 36, (Elsevier, Amsterdam, 1975).
11. Committee on Public Engineering Policy, National Academy of Engineering, *A Study of Technology Assessment* (Government Printing Office, Washington, D.C., 1969).
12. E. B. Skolnikoff and H. Brooks, *Science* 187, 35 (1975).
13. There are clear indications that scientists are beginning to acknowledge the need for explicit methods for decision-making in areas where science and the public interest intersect. Two recent NAS committee reports (*Environmental Impact of Stratospheric Flight* (1975); *Decision Making for Regulating Chemicals in the Environment* (1975)) as well as others mentioned in the latter describe the application of normative decision theory to such problems. Although these efforts represent a clear step forward through their insistence on the use of an explicit framework for decisions, they do not indicate how such decisions might be assisted or improved through the study of human judgment.
14. For a general review of current research on

- judgment and decision-making see [P. Slovic, B. Fischhoff, S. Lichtenstein, in *The Annual Review of Psychology* (Annual Reviews, Palo Alto, Calif., in press), vol. 28]. See also M. Kaplan and S. Schwartz, Eds., *Human Judgment and Decision Processes* (Academic Press, New York, 1975); W. Edwards, M. Guttentag, K. Snapper, in *Handbook of Evaluation Research*, E. L. Struening and M. Guttentag, Eds. (Sage, Beverly Hills, Calif., 1975), vol. 1; R. A. Howard, in *Proceedings of the Fourth International Conference on Operational Research* (Wiley-Interscience, New York, 1966); H. Raiffa, *Decision Analysis: Introductory Lectures on Choices Under Uncertainty* (Addison-Wesley, Reading, Mass., 1968).
15. Can the adversary system produce this confusion of roles at the national level, and does it have similar negative effects? Apparently it can, and does. For example, in Polsby's review of Boffey's book, Polsby (7, p. 666) states: "Boffey notes, in criticizing a National Academy of Engineering committee on pollution abatement, that it was no more qualified than any other group of citizens to judge what should be 'wise' public policy." (In this instance, Boffey argues that scientists overstepped their bounds and should have confined their role to presenting the facts.) "Sound doctrine," observes Polsby, "and yet Boffey criticizes another of the Academy's committees for taking on an assignment pertinent to a naval communications project that did not include evaluating its 'desirability,' and for not venturing to raise 'questions as to the basic worth' of the space shuttle program." (In this instance, Boffey argues that scientists failed to help form social policy and thus failed in their responsibility to the public.) Thus, concludes Polsby, "the Academy is damned if it does pronounce on the overall wisdom of public policies, and damned if it doesn't."
  16. Public Broadcasting Service, "Black Horizons," 16 February 1975.
  17. K. R. Hammond, T. R. Stewart, L. Adelman, N. Wascoe, *Report to the Denver City Council and Mayor Regarding the Choice of Handgun Ammunition for the Denver Police Department* (Report No. 179, University of Colorado, Institute of Behavioral Science, Program of Research on Human Judgment and Social Interaction, Boulder, 1975).
  18. To determine the relative importance a person places on each characteristic, linear multiple regression analysis was performed to obtain the beta weights on each of the three judgment dimensions, or factors. The absolute value of the beta weight for a factor was then divided by the sum of the absolute values of the beta weights over all factors to determine the relative weight, or importance placed on each factor. The relative weights were displayed on the computer console. For technical details on the procedure see [K. R. Hammond, T. R. Stewart, B. Brehmer, D. O. Steinmann, in *Human Judgment and Decision Processes*, M. Kaplan and S. Schwartz, Eds. (Academic Press, New York, 1975)].
  19. The judgment dimensions were defined as follows: (i) *Stopping effectiveness*: the probability that a 20- to 40-year-old man of average height (5'10") and weight (175 lbs) shot in the torso would be incapacitated and rendered incapable of returning fire. Judgments ranged from 0 to 100, indicating, on the average, how many men out of 100 would be stopped by a given bullet. (ii) *Severity of injury*: the probability that a man, as described above, shot in the torso would die within 2 weeks of being shot. (iii) *Threat to bystanders*: penetration was defined as the probability that a bullet would pose a hazard to others after passing through a person shot in the torso at a distance of 21 feet. Ricochet was defined as the probability that a bullet would pose a hazard after missing the intended target at a distance of 21 feet.
  20. The separation of stopping effectiveness from injury that is indicated in the graph for bullet 9 was not due to inconsistencies and inaccuracies in the experts' ratings. The three medical experts agreed that the shape of the temporary cavity is an indicator of differences in severity of injury for bullets with the same stopping effectiveness. More severe wounds are produced by bullets that have a long, wide temporary cavity; less severe wounds localize the maximum diameter of their temporary cavity and do not penetrate deeply. According to all three experts, a temporary cavity that reaches a maximum diameter of 10 to 15 cm at 5 to 7 cm from the surface, and does not penetrate more than 15 cm, would provide the best compromise between stopping effectiveness and survivability.
  21. The time, manpower, and cost of the handgun study were as follows: (i) The project was completed in 6 weeks and (ii) research personnel included four people of whom one worked full time. Total cost, including salaries of the project staff, did not exceed \$6000; an additional \$3500 was required to pay the travel and consulting costs of the ballistics experts.
  22. For examples of the application of a hierarchical framework, see K. R. Hammond, J. Rohrbaugh, J. Mumpower, L. Adelman, in *Human Judgment and Decision Processes: Applications in Problem Settings*, M. F. Kaplan and S. Schwartz, Eds. (Academic Press, New York, 1976).
  23. J. Rawls, *A Theory of Justice* (Harvard Univ. Press, Cambridge, Mass., 1971).
  24. Supported by National Institute of Mental Health grant MH-16437. We thank S. Cook, D. Deane, and B. Fischhoff, among many others, for their help.